DRAFT SUPPLEMENTAL WATERSHED PLAN AND ENVIRONMENTAL ASSESSMENT FOR THE

VINEYARD ROAD AND RITTENHOUSE FLOOD RETARDING STRUCTURES

PINAL COUNTY, ARIZONA

Prepared by:

East Maricopa Natural Resource Conservation District

Flood Control District of Maricopa County, Arizona
FCD 2008C042

Assisted by:
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Natural Resources Conservation Service

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**Draft Supplemental Watershed Project Plan and Environmental Assessment
for the
Vineyard Road and Rittenhouse Flood Retarding Structures
Pinal County, Arizona**

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and
Flood Control District of Maricopa County
2801 W. Durango Street, Phoenix, Arizona 85009

Assisted by:
United States Department of Agriculture
Natural Resources Conservation Service

AUTHORITY
The original watershed work plan was prepared, and works of improvement have been installed, under the authority of the Watershed Protection and Flood Prevention Act of 1954 (Public Law 83-566) as amended. This Supplemental Watershed Plan and Environmental Assessment is authorized under Public Law 83-566 (as amended), and as further amended by Section 313 of Public Law 106-472 and in accordance with Section 102(2)c of the National Environmental Policy Act of 1969, Public Law 91-190, amended (42 USC 4321 et seq).

ABSTRACT
The Vineyard Road and Rittenhouse Flood Retarding Structures (FRS) were constructed by the Soil Conservation Service (now the Natural Resources Conservation Service – NRCS) in 1968 and 1969, respectively, as part of the Williams-Chandler Watershed Protection and Flood Prevention Project. The flood retarding structures are operated and maintained by the Flood Control District of Maricopa County (District). Vineyard Road FRS, a 5.5 mile long, 16.5 foot high earth dam, and Rittenhouse FRS, a 3.6 mile long, 24.3 foot high earth dam, provides flood protection to downstream residents, structures, and infrastructure.

The FRSs have developed safety deficiencies and both dams are approaching on the original 50-year project lifetimes. The embankments of the dams are experiencing longitudinal and transverse cracking and the auxiliary spillways for each dam do not have the capacity to pass the inflow design flood. In 2009, the District requested Federal planning and implementation assistance for long-term solutions to the identified dam safety deficiencies. The rehabilitation of the structures will require raising the dams with earthfill, replacing the existing principal spillways with new risers and outlets, installing new embankment filters, raising the crest of the auxiliary spillways, and providing structural auxiliary spillways. This Supplemental Watershed Plan and Environmental Assessment (Plan/EA) determines the feasibility of rehabilitation the FRSs to provide for continued flood protection while meeting current applicable local, State, and Federal regulations.

COMMENTS AND INQUIRIES
Comments and inquiries must be received by March 12, 2013. Submit comments and inquiries to: Keisha L. Tatem, State Conservationist, USDA, Natural Resources Conservation Service, 230 North First Avenue, Suite 509, Phoenix, Arizona, 85003 (Telephone: (602) 280-8801).

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1.0 SUMMARY SUPPLEMENTAL WATERSHED PLAN AND ENVIRONMENTAL ASSESSMENT

Project Name: Vineyard Road and Rittenhouse Flood Retarding Structures (FRSs)

County: PINAL State: ARIZONA Congressional District: 6

Authorization: Public Law 83-566 Stat. 666 as amended (16 U.S.C. Section 1001 et. Seq.) 1954

Sponsors: Flood Control District of Maricopa County, Arizona

East Maricopa Natural Resource Conservation District

Proposed Action: Rehabilitation of the Vineyard Road FRS and Decommission of the Rittenhouse FRS by converting to levee.

Purpose and Need for Action: The purpose of the proposed project is flood prevention. The Vineyard Road FRS and Rittenhouse FRS provide flood protection to portions of eastern Maricopa County and western Pinal County, Arizona. The dams are being evaluated due to concerns regarding the foundation (subsidence), central filters, embankment cracking, and the inability to safely pass the inflow design flood.

The Preferred Alternative will meet the project purpose of providing for continued flood protection for the downstream benefitted area and reducing the risk of loss of life due to catastrophic dam failure. Action is needed to address public health and safety issues surrounding a flood control dam that does not meet existing safety and performance standards for a high hazard potential structure.

Description of Preferred Alternative: The Preferred Alternative for the Vineyard Road FRS is rehabilitation and for Rittenhouse FRS is to convert the dam to a levee. The Vineyard Road FRS rehabilitation includes measures to rehabilitate the dam by raising the dam, constructing a new filter, and installing improvements for the principal and auxiliary spillways. The Rittenhouse FRS will be converted to a levee by removing the right (west) abutment so that flood flows from the Rittenhouse watershed flow into the Vineyard Road FRS flood pool. The Rittenhouse FRS will be lowered (materials removed from the top of the dam) to a height of the 100-year flood elevation plus a minimum of three feet of freeboard. Material used to raise the height of the Vineyard Road FRS may be derived from several sources including borrow from the Vineyard Road FRS flood pool and/or from excavation of the Powerline Channel (under a separate but related construction activity). The spoils from construction activities will be stockpiled within the Sponsor's easements.

Resource Information**:**

- Latitude and Longitude: The existing Vineyard Road FRS is located at 33.3197° N Latitude, and 111.5241° W Longitude. The existing Rittenhouse FRS is located at 33.2808° N Latitude, and 111.5027° W Longitude.
- Hydrologic Unit Number: The 8-digit Hydrologic Unit Code (HUC) for the Vineyard Road FRS and Rittenhouse FRS contributing watersheds and downstream inundation areas is the Middle Gila Watershed – 15050100.

Climate and Topography: The upstream contributing watershed for the Vineyard Road and Rittenhouse FRSs originates in the southwest facing slopes of the Superstition Mountains with steep mountain topography. The mountains drain onto a wide alluvial fan with various land uses and flattening topography. The downstream inundation area is a largely flat topography with mixed land uses. The climate is typical of the arid southwest with mild winters and hot summers. Rainfall is limited and typically occurs in either the winter wet period or the summer monsoon period

Vineyard Road Watershed size: approximately 21,019 acres in the downstream breach inundation area; Approximately 33,728 acres in the upstream contributing watershed.
Rittenhouse Watershed size: approximately 30,272 acres in the downstream breach inundation area; Approximately 36,087 acres in the upstream contributing watershed.

Land Uses: The downstream area consists of open space, residential and commercial/industrial developments, agriculture and open space. The upstream contributing watershed consists primarily of open space.

Land Ownership Information (downstream area from FRSs): Private Land – 87%, State/Local 12%, Federal 1%.

Population and Demographics: The current residential population in the study area downstream of the FRSs is estimated at 91,700. The population at risk of flooding downstream of the Vineyard Road FRS is estimated at 25,868 and for Rittenhouse FRS is 38,700. The beneficiary profile is relatively representative of the Pinal and Maricopa County's population at large. The majority of the total population encompassing the Powerline, Vineyard Road and Rittenhouse FRSs (PVR FRSs) area is White which comprises 86.9% of the population. The total minority population is 13.1% with the breakdown of racial and ethnic demographics as follows: Black or African American 1.4%; American Indian and Alaskan Native 1.0%; Asian 1.2%; Native Hawaiian and other Pacific Islander 0.2%; Other 6.6%; Population of Two or More Races/Not Hispanic or Latino 2.8%. The percentages of racial, ethnic and total minority populations appear to be consistent with those of the surrounding communities.

The demographics were conducted on the area defined as the 'Social Population Demographics Existing Conditions Study area' (SPDECS) for the Powerline, Vineyard Road, and Rittenhouse FRSs and documented in the "Social, Population and Demographics Existing Conditions Study" (Kimley-Horn July, 2010). The analysis approach was based on Census Track and Block Groups within and adjacent to the SPDECS study area. The source of the data is the decennial Census 2000 data sets from the United States Census Bureau (Census 2000). The SPDECS study is summarized in **Appendix D.**

The median household income for the PVR FRSs area is between $32,055 and $101,124 for an average median household income of $60,789. This represents a slightly higher median household income than the neighboring communities which range between $33,170 (Apache Junction) and $68,032 (Gilbert) for an average median household income of $58,399.

Resource Concerns: The following is a listing of the relevant resource concerns considered during the scoping process.

Aesthetics: Structures are significant features on the landscape.

Cultural Resources: Previous cultural resources surveys and research in the vicinity suggest that there would be a significant number of archaeological sites located within the area of potential effects (APE) for the project.

Environmental Justice: Minority and disadvantages populations downstream of dam are at high risk if no action is taken.

Fish and Wildlife: No fish present in the project area. Mesquite Bosque habitat located upstream of structure.

Flooding: Homes, businesses, and infrastructure are at high risk of flood damages if no action is taken.

Migratory Birds: The project area contains suitable habitat for the western burrowing owl (*Athene cunicularia hypugaea*) which is protected under the Migratory Bird Treaty Act.

Prime Farmland: Prime farmland downstream of structure is at high risk of flood damages if no action is taken.

Public Health and Safety: Public health and safety is at high risk in the event of a catastrophic failure of the dam if no action taken.

Transportation: Major local roads are located downstream and area at high risk of flood damage if no action is taken.

Threatened and Endangered Species: The U.S. Fish and Wildlife Service (USFWS) threatened, endangered, proposed, and candidate species list for Pinal and Maricopa Counties, as well as the Arizona Game and Fish Department (AGFD) Heritage Data Management System (HDMS), were reviewed. There are no known occurrences of any threatened or endangered species critical habitat within the project area.

Suitable habitat is present for the Tucson shovel-nosed snake (*Chionactis occipitalis klauberi*) and dispersal habitat is present for the Sonoran desert tortoise *(Gopherus agassizii)*. These are candidate species for the USFWS and may become listed in the future and warrant additional assessment. Desert tortoise has the potential to occur within the project area.

Additionally, the project contains suitable habitat for the western burrowing owl (*Athene cunicularia hypugaea*) which is protected under the Migratory Bird Treaty Act. Prior to start of construction, a survey for burrowing owls will be required in the disturbance area following the AGFD protocol (January 2009).

Vegetative Community: Mesquite Bosque located upstream of structures.

Water Resources: The Central Arizona Project canal is located downstream of the structure and is at high risk of flood damages if no action is taken.

Wetlands: None

Alternative Plans Considered: The project alternatives that were considered as part of this study include the following:

- No Federal Action/Future Without Project: Vineyard Road FRS and Rittenhouse FRS remain in existing conditions until Sponsor's eventual Rehabilitation or Replacement of the dams;
- Decommissioning by Replacing the Rittenhouse FRS with a Channel to Vineyard Road FRS; Raise and Rehabilitate the Vineyard Road FRS;
- Decommissioning by Replacing the Rittenhouse FRS with a Levee to Vineyard Road FRS; Raise and Rehabilitate the Vineyard Road FRS;
- Raise and Rehabilitate the Vineyard Road FRS and Rittenhouse FRS.

Estimated Project Costs:

Item (Vineyard Road FRS)	PL 83-566 Funds ($)	Other Funds ($)	Total ($)
Construction Cost	$27,403,500	$13,541,300	$40,944,800
Technical Assistance	$600,000	$1,204,400	$1,804,400
Project Administration	$50,000	$10,000	$60,000
Land Rights (Sponsors)	$0	$0	$0
Required Permits (Sponsors)		$803,000	$803,000
Total	$28,053,500	$15,558,700	$43,612,200

The annual operation and maintenance cost for the Vineyard Road FRS is $248,900.

Item (Rittenhouse FRS)	PL 83-566 Funds ($)	Other Funds ($)	Total ($)
Construction Cost	$5,527,800	$2,723,800	$8,251,600
Technical Assistance	$600,000	$242,700	$842,700
Project Administration	$50,000	$10,000	$60,000
Land Rights (Sponsors)	$0	$0	$0
Required Permits (Sponsors)		$161,800	$161,800
Total	$6,177,800	$3,138,300	$9,316,100

The annual operation and maintenance cost for the Rittenhouse FRS is $42,800

Estimated Project Benefits:

An estimated number of current residents downstream of the Vineyard Road FRS is 25,868 and for Rittenhouse FRS is 38,700, with associated homes, businesses, and infrastructure are protected from catastrophic dam failure and flooding. Additional residents and infrastructure will be protected in the future as development continues to occur in the downstream benefitted area.

Category (Vineyard Road FRS)	Average Annual Equivalent Benefits
Beneficial Annual[1/]	$0
Adverse Annual	$1,697,600
Net Beneficial	($1,697,600)
Benefit-Cost Ratio	0.0 to 1.0

Category (Rittenhouse FRS)	**Average Annual Equivalent Benefits**
Beneficial Annual[1/]	$0
Adverse Annual	$352,900
Net Beneficial	($352,900)
Benefit-Cost Ratio	0.0 to 1.0

[1/] / The proposed project will provide an estimated $182,400 and $4,021,700 in average annual equivalent damage reduction benefits at Vineyard FRS and Rittenhouse FRS, respectively. However, as the "no action" or future without project alternative also provides this same benefit stream, the project does not have a positive incremental benefit. The benefits of the project are tied to reducing the risk of catastrophic failure of the existing structures and thus reducing the risk to life and property, as described in the plan.

Funding Schedule: Vineyard Road FRS FY 2018; Rittenhouse FRS FY 2024 (Powerline FRS FY 2022)

Period of Analysis: 103 Years

Project Life: 100 Years

Environmental Effects and Impacts:

1. Cultural Resources – Sites in the area of potential effects that will not be subject to project-related impacts will be avoided by project implementation activities. Data recovery studies will be performed to mitigate impacts to all sites likely to suffer project-related impacts. Based on known sites in the vicinity, the majority of the cultural resources present would be either prehistoric sites without evidence of habitation (which might include scatters of artifacts on the surface, or artifacts with remnants of just one or a few roasting pits, agricultural features, and/or other non-habitation features) or historical sites (which might include homesteads, farming or ranching features, or simply scatters of historical artifacts). Most of the remaining sites would be smaller prehistoric habitation sites, with up to two relatively large prehistoric habitation sites.
2. Threatened and Endangered Species – Survey protocol for the Tucson shovel-nosed snake has not been published by the USFWS. Prior to construction the status of the Tucson shovel-nosed snake on the USFWS threatened, endangered, proposed, and candidate list will be re-verified (i.e. status changed from candidate to threatened) and coordination with the USFWS will be undertaken to determine if a survey protocol has been established and/or if a survey is required. If this species is observed construction will cease until measures can be taken to ensure the preservation of the snake and/or its habitat. Prior to start of construction, the project area will be canvassed for tortoises and, if any tortoises are discovered, AGFD guidelines (October 2007) will be followed. Prior to start of construction, a survey for burrowing owls will be conducted in the disturbance area following the AGFD protocol (January 2009). As a result of the actions described above, there will be no effect on federally threatened and endangered species or their critical habitat due to implementation of this alternative. The above-mentioned mitigation measures will be utilized to minimize impacts to special status species.
3. Vegetative Community - Areas disturbed associated with construction activities will be hydro-seeded with native mix. Approximately 105 acres of mesquite bosque will be impacted. Mesquite bosque mitigation may include planting new tall-pot mesquite trees

(approximately 100 acres) and salvage of some mature mesquite trees and transplanting in designated areas (e.g., along Powerline Channel and potential mitigation area at north end of Vineyard Road FRS, and along Vineyard and Rittenhouse). Mitigation plans will be refined during final design.

Major Conclusions: The rehabilitation of the Vineyard Road FRS and converting Rittenhouse FRS to a levee will continue to provide 100-year flood protection for the downstream benefitted area. This alternative will reduce the risk of loss of life to the people that live and work below these existing dams. No significant adverse environmental effects will result from implementation of this project.

Areas of Controversy: None.

Issues to be Resolved: None

Evidence of Unusual Congressional or Local Interest: None

This report is in compliance with executive orders, public laws, and other statues governing the formulation of water resource projects.

2.0 PURPOSE AND NEED FOR ACTION

2.1 CHANGES REQUIRING PREPARATION OF A SUPPLEMENT

The Vineyard Road and Rittenhouse FRSs are classified by the Arizona Department of Water Resources (ADWR) and NRCS as high hazard structures. These dams do not meet current dam safety and performance standards. The dams have known deficiencies in the embankment (transverse and longitudinal cracking and erosion holes), located in an area with land subsidence (Vineyard Road FRS) and inadequacies in auxiliary spillway capacities. There is a risk to downstream structures and inhabitants if no action is taken to rehabilitate or replace the structures.

The NRCS addressed deficiencies due to transverse cracking at both dams by means of repair projects that were completed in 1982/1983 and 1979 for the Vineyard Road FRS and Rittenhouse FRS, respectively. The repair projects included installation of a central embankment filter along the dams. The projects were funded under the NRCS Watershed Operations program. Current conditions indicate additional transverse and longitudinal cracks as well as erosion holes in the embankments are present. Remaining inadequacies in auxiliary spillway capacities are considered under this study.

This Supplemental Watershed Plan and Environmental Assessment (Plan/EA) addresses the identified dam safety deficiencies (noted above) by evaluating alternatives to either rehabilitate or replace the Vineyard Road FRS and/or the Rittenhouse FRS. The Plan/EA determines the feasibility of raising and rehabilitation of the Vineyard Road FRS and decommissioning the Rittenhouse FRS by converting the Rittenhouse FRS to a levee to provide for continued flood protection while meeting current applicable local, State, and Federal regulations. The changes being made are to raise the height of and rehabilitate the Vineyard Road FRS by installation of a new filter and modification of the principal and auxiliary spillways. The Rittenhouse FRS will be converted to an earthen levee by removal of the right (north) abutment in order for flows from Rittenhouse to discharge to the Vineyard Road FRS. Rittenhouse will be lowered to a height sufficient for the 100-year flows plus three feet of freeboard.

The **purpose and need** of the proposed project is to provide continued flood protection for the downstream benefitted area and to reduce the risk of loss of life due to catastrophic dam failures. Action is needed to address public health and safety issues surrounding flood control dams that do not meet existing safety and performance standards for high hazard potential structures.

2.2 BACKGROUND

The Vineyard Road and Rittenhouse Flood Retarding Structures provide substantial flood protection benefits to portions of Maricopa and Pinal Counties, City of Mesa, Town of Queen Creek, State Lands, and surrounding areas. The FRSs protect public infrastructure including streets and highways, residential and commercial properties and large areas of prime farmland.

In June 2000, the Sponsor completed an Individual Structure Assessment for the Vineyard Road and Rittenhouse Flood Retarding Structures and in August 2000 the Sponsor completed an Alternatives Analysis Report for the Vineyard Road and Rittenhouse Flood Retarding Structures. In July 2009, the Sponsor entered into a Memorandum of Understanding with the Natural Resources Conservation Service (NRCS) to cooperatively conduct planning, design and implementation of a preferred alternative needed to address the identified inadequacies. In July

2009, the Sponsor initiated the planning phase. This Plan/EA is being prepared during this planning phase.

The Vineyard Road and Rittenhouse FRSs are two of three earthen flood retarding structures (Powerline FRS is the third) located east of the Central Arizona Project (CAP) canal. The three structures were originally designed by the NRCS to operate as an integrated system as the principal spillways at Powerline FRS and Vineyard Road FRS both discharge into a common channel – the Powerline Floodway. The Rittenhouse FRS principal spillway discharges into the Vineyard Road FRS flood pool. The result is that all three principal spillways eventually flow into the Powerline Floodway. The Powerline, Vineyard Road, and Rittenhouse FRSs Rehabilitation or Replacement Project (Project) was initiated to formulate alternatives to mitigate identified dam safety deficiencies at the three dams. One of the objectives in the formulation of alternatives for the three dams was to maintain the integrated operational relationship of the three dams (or alternatives) to discharge to the Powerline Floodway. This Supplemental Watershed Plan and Environmental Assessment (Plan/EA) presents the alternatives evaluated and preferred alternative for Vineyard Road and Rittenhouse FRSs. The Vineyard Road and Rittenhouse FRSs are structural plan elements of the Williams-Chandler Watershed Work Plan. A separate Supplemental Watershed Plan/EA has been prepared for the Powerline FRS as this dam is a structural element of the Apache Junction-Gilbert Watershed Work Plan.

2.3 Existing Dam Conditions

2.3.1 Location

The Vineyard Road and Rittenhouse Flood Retarding Structures are located in northwest Pinal County, Arizona. The structures are east of Mesa and the Town of Queen Creek. The Vineyard Road and Rittenhouse Flood Retarding Structures are two of three flood retarding structures designed and constructed by the NRCS to provide flood control benefits to portions of Maricopa and Pinal County (the other is the Powerline FRS). The contributing watersheds originate in the southwest-facing slopes of the Superstition Mountains. The total watershed area contributing to the three structures is 147 square miles and includes Weekes Wash and Siphon Draw. Queen Creek Wash is located south of the structures. The Central Arizona Project canal (CAP) is aligned west of the structures. The PVR FRSs alignments extend south from Baseline Road to the Ocotillo Road alignment, approximately 12 miles in length. A project map for the Vineyard Road FRS and Rittenhouse FRS and associated features is provided in **Appendix B.**

The Vineyard Road and Rittenhouse Flood Retarding Structures, outlet works, and flood pools lie within the following sections (Gila and Salt River Baseline & Meridian).

<u>Vineyard Road FRS</u>

Township 1 South, Range 8 East, Sections 21, 22, 27, and 34

Township 2 South, Range 8 East, Section 2 and 3

<u>Rittenhouse FRS</u>

Township 2 South, Range 8 East, Section 2, 11, 13, and 14

The dams, outlet works and the flood pools are located on land that is owned by the State of Arizona. The Sponsor has obtained easements from the State of Arizona to operate and maintain the dams and appurtenant structures. The Vineyard Road and Rittenhouse Flood Retarding Structures provide 100-year flood protection from flood flows originating from a 99.8-square-mile watershed. The State of Arizona (State Land Department) has prepared or is in the process of preparing land use plans to areas both upstream and downstream of the dams.

2.3.2 Embankment and Reservoir Pool

The Vineyard Road FRS embankment extends southeast from 1,600 feet southeast of Powerline FRS, parallel to the CAP canal. The FRS is a homogeneous earthen embankment 28,829 feet (5.5 miles) in length, with a maximum height of 16.5 feet. The embankment crest elevation was designed at 1,581.5 feet, and the auxiliary spillways were designed at 1,576.8 feet to provide 4.7 feet of freeboard. The reservoir capacity is 4,310 acre-feet which provides for 178 acre-feet of sediment and 4,132 acre-feet of flood water. At full capacity, the sediment pool area and flood pool area would be 150 acres and 840 acres, respectively. The maximum recorded impoundment for the Vineyard Road FRS was 897 acre-feet with a flood stage of 5.9 feet on January 11, 1993. Other historical storms of note include an October 1972 storm, where the reservoir stage may have reached the auxiliary spillway crest and floodwaters may have flowed through the auxiliary spillway. The FRS flood pool under normal operations is dry, only temporarily impounding water in response to runoff events. The FRS does not have a permanent water pool.

A central filter was installed in the Vineyard Road FRS in 1982/1983 which extends along the entire length of the embankment (from Stations 85+00 to 360+700). The filter extends to at or near foundation.

The Rittenhouse FRS embankment extends southeast from Vineyard Road FRS, parallel to the CAP canal. The FRS is a homogeneous earthen embankment 19,008 feet (3.6 miles) in length, with a maximum height of 24.1 feet. The embankment crest elevation was designed at 1604.3 feet, and the auxiliary spillway was designed at 1599.5 feet to provide 4.7 feet of freeboard. The reservoir capacity is 4,060 acre-feet which provides for 175 acre-feet of sediment and 3,885 acre-feet of flood water. At full capacity, the sediment pool area and flood pool area would be 118 acres and 660 acres, respectively. The maximum recorded impoundment for the Rittenhouse FRS was 919 acre-feet with a flood stage of 12.58 feet on February 12, 2005. Other historical storms of note include an October 1972 storm, where the reservoir stage may have reached the auxiliary spillway crest and floodwaters may have flowed through the auxiliary spillway. The FRS flood pool under normal operations is dry, only temporarily impounding water in response to runoff events. The FRS does not have a permanent water pool.

Typical sections of the existing embankments for Vineyard Road FRS and Rittenhouse FRS are provided in **Appendix C** as **Figure C-1** and **Figure C-5**, respectively.

2.3.3 Principal Spillways

Flows entering the Vineyard Road FRS impoundment are routed through a low-flow channel to the principal spillway. The spillway is an ungated, 100-foot long, 54-inch diameter reinforced concrete pipe (RCP) located at the northern abutment of the FRS. The pipe is situated on a concrete cradle and three seepage cutoff collars are spaced at 20-foot intervals along the pipe. At the upstream inlet of the spillway, there is a trash rack to filter debris and the spillway discharges into a concrete lined channel through an outlet structure. The downstream outlet of the principal spillway features an energy dissipater, and the principal spillway discharge capacity is 368 cubic feet per second (cfs) at the crest elevation of the auxiliary spillway.

Flows entering the Rittenhouse FRS impoundment are routed through a low-flow channel to the principal spillway, which discharges into the Vineyard Road FRS flood pool. The spillway is an ungated, 145-foot long, 33-inch diameter reinforced concrete pipe (RCP) located at the northern abutment of the FRS. The pipe is situated on a concrete cradle and five seepage cutoff collars are spaced at 20-foot intervals along the pipe. At the upstream inlet of the spillway, there is a trash rack to filter debris and the spillway discharges into a concrete lined channel through an outlet structure. The downstream outlet of the principal spillway features an energy dissipater, and the principal spillway discharge capacity is 143 cubic feet per second (cfs) at the crest elevation of the auxiliary spillway.

Typical sections of the existing principal spillways for Vineyard Road FRS and Rittenhouse FRS are provided in **Appendix C** as **Figure C-2** and **Figure C-6**, respectively.

2.3.4 Auxiliary Spillways

The Vineyard Road FRS auxiliary spillways are located at the northern and southern abutments of the FRS. Both spillways are 300-foot wide excavated earthen open channels with a combined capacity of 12,800 cfs. The control sections of the auxiliary spillways are compacted, benched sills, located one foot above level upstream approach channels. The approach channels are on constructed bends that directs flows around the abutments of the FRS.

The Rittenhouse FRS auxiliary spillway is located at the southern abutment of the FRS. The spillway is a 600-foot wide excavated earthen open channel with a capacity of 12,800 cfs. The control section of the auxiliary spillways is a compacted, benched sill, located one foot above the level upstream approach channel. The approach channel is on a constructed bend that directs flows around the abutment of the FRS.

Typical sections of the existing auxiliary spillways for Vineyard Road FRS and Rittenhouse FRS are provided in **Appendix C** as **Figure C-3** (Vineyard South), **Figure C-4** (Vineyard North) and **Figure C-7** (Rittenhouse).

2.4 Inadequacies of Structures

The Arizona Department of Water Resources (ADWR) conducts inspections of jurisdictional dams throughout the state. Powerline and Vineyard Road FRSs were recently inspected on January 30, 2012 and Rittenhouse was inspected on January 31, 2012. The ADWR dam safety inspection reports (published April 13, 2012) found no safety deficiencies for the Vineyard Road and Rittenhouse FRSs.

ADWR identified one maintenance action item for Vineyard Road FRS and Rittenhouse FRS. ADWR noted that the action item as removing rodent burrowing on the structures in a timely manner.

ADWR has reviewed the size and hazard potential classifications for the dams. The classifications have not changed from intermediate size and high hazard potential.

Although ADWR dam safety inspection reports stated no safety deficiencies for the Vineyard Road FRS and Rittenhouse FRS, previous and continuing engineering investigations and studies by the Sponsor indicate deficiencies exist and are briefly described in **Sections 2.1** above and **2.4.1** below.

2.4.1 *Updated Hydrologic/Hydraulic Investigations*

Updated hydrologic/hydraulics (H/H) investigations and studies were conducted during the planning study for the Vineyard Road and Rittenhouse FRSs. These studies evaluated the operational response of the structures and principal and auxiliary spillways for existing land use and future land use conditions for multi-frequency events (2-yr through 500-yr). The investigations completed a planning level probable maximum precipitation/probable maximum flood (PMP/PMF) study to determine a planning level recommendation for the PVR structures for the inflow design flood (IDF). The results of the planning level PMP/PMF indicates that the 6-hr PMF is the more conservative over the 24-hr and 72-hr events. The planning level study recommended a reduction of the planning PMP/PMF to approximate an anticipated reduction of the PMP should a future site specific PMP study be conducted for the three PVR watersheds. The updated H/H evaluations also conducted NRCS SITES modeling for the three dams to determine the principal spillway hydrograph (PSH), stability design hydrograph (SDH), and the integrity or freeboard hydrograph (FBH). The SITES study included an allowable stress evaluation of the earth lined spillways and a breach analyses.

The results for Vineyard Road FRS indicates that:

- Overtopping of the dam crest during the existing conditions 6-, and 72-hour PMP.
- Overtopping of the dam crest during the future conditions 6-, 24-, and 72-hour PMP.
- Existing conditions principal spillway hydrograph draw down is longer than 10 days (13.7 days).
- Future conditions principal spillway hydrograph draw down is longer than 10 days (14.2 days).
- South auxiliary spillway erodes during the future conditions stability design hydrograph.
- Both auxiliary spillways breach during the existing and future conditions freeboard design hydrograph.

The results for Rittenhouse FRS indicate that:

- Overtopping of the dam crest during the existing and future conditions 6-, 24-, and 72-hour PMP.
- Existing and future conditions principal spillway hydrograph draw down is longer than 10 days (12.0 days).
- Auxiliary spillway breaches during the existing and future conditions freeboard design hydrograph.

2.5 Regulatory Considerations

The Vineyard Road and Rittenhouse Flood Retarding Structures are under the jurisdiction of ADWR and NRCS. The dams must comply with dam safety rules and regulations of these dam safety agencies.

3.0 SCOPE OF PLAN/EA

The scoping process followed the general procedures contained in the Water Resources Council's Principles and Guidelines and Section 501.35 of the NRCS National Watershed Program Manual. The procedures require that environmental and cultural resources be considered early in the planning process by an interdisciplinary team of technical specialists, in consultation with all interested parties.

The scoping process was used during development of the Vineyard Road and Rittenhouse FRS Supplemental Watershed Plan and Environmental Assessment to focus planning efforts on problems and opportunities of most importance to all interested parties. Scoping was utilized to focus the goals of the planning effort and thereby narrow the range of identified alternatives. Comments and questions were solicited from local citizens, groups, and local, State, and Federal agencies throughout the planning effort. Public and/or agency comments were received. Several identified concerns were identified by the Sponsors and project team and are listed in **Table 3 -** 1 below.

Two public meetings where held during the planning process for the Powerline, Vineyard Road, and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project. The first meeting was held on November 4, 2010. This purpose of this meeting was to introduce the public to the project location and purpose and need for the project. The second meeting was held on February 1, 2011. The purpose of this meeting was to solicit input from the public regarding planning alternatives for the PVR project. Meeting notices/announcements were published in local newspapers and mailed to several Federal and State agencies. The Sponsor provided a program overview at both public meetings. At the second meeting Kimley-Horn and Associates, Inc. provided an overview of the study alternatives that were developed and presented for public input. Several comments were received by the public at the second public meeting.

A third public meeting is scheduled for February 12, 2013 during the public review period. The purpose of this meeting will be to present the preferred alternative as described in this draft Plan/EA and to solicit comments and questions regarding the proposed project.

The **purpose and need** for the project is to provide continued flood protection and to reduce the risk of loss of life due to catastrophic dam failure and flooding. Action is needed to address public health and safety issues surrounding a flood control dam that does not meet existing safety and performance standards for a high hazard potential structure.

Table 3 - 1 Evaluation of Identified Concerns

ITEM/CONCERN	Relevant to the proposed action?[1/]		RATIONALE
	Yes	No	
SOILS			
Upland Erosion		X	No concerns in study area.
Stream Bank Erosion		X	No concerns in study area.

Table 3 – 1 Evaluation of Identified Concerns (continued)

ITEM/CONCERN	Relevant to the proposed action?[1/]		RATIONALE
	Yes	No	
SOILS			
Geology	X		Regional land subsidence at the northern 1/3 of Vineyard Road FRS is expected to continue in the near future. Continued monitoring and investigations for land subsidence.
Sedimentation		X	No concerns in study area.
Prime and Unique Farmland	X		Structures provide flood protection to downstream Prime Farmland.
WATER			
Surface Water Quality		X	No impaired streams or lakes in project area.
Surface Water Quantity	X		Structure spillways do not have adequate capacity to safely convey probable maximum flood.
Groundwater Quantity		X	Groundwater pumping in area has contributed to land subsidence and earth fissures.
Clean Water Act		X	No concerns in study area.
Regional Water Mgt Plans	X		Project provides flood protection for Central Arizona Project Canal.
Floodplain Management	X		Home, businesses, and infrastructure are at high risk of flood damages in the event of a catastrophic failure of the dam if no action is taken.
Wetlands		X	None Present
Wild and Scenic Rivers		X	None Present
Ecologically Critical Areas		X	None Present
Sole Source Aquifers		X	None Present
AIR			
Air Quality		X	No concerns in study area.
Clean Air Act		X	Air permit required for construction activities
PLANTS			
Threatened and Endangered Species		X	No occurrences in study area.
Essential Fish Habitat		X	No fish habitat in study area
Invasive Species		X	Minimal invasive species present on study area
Natural Areas		X	No natural areas in study area
Riparian Areas		X	No riparian areas in study area

Table 3 – 1 Evaluation of Identified Concerns (continued)

ITEM/CONCERN	Relevant to the proposed action?[1/] Yes	No	RATIONALE
PLANTS			
Forest Resources		X	Not Applicable
Parklands		X	None Present
Vegetative Communities	X		Mesquite Bosque located upstream of structure
ANIMALS			
Fish and Wildlife Habitat	X		No fish present in study area. Mesquite Bosque habitat located upstream of structure.
Threatened and Endangered Species		X	No occurrences in study area.
Invasive Species		X	Minimal invasive species present on study area
Migratory Birds/Bald and Golden Eagles	X		Potential habitat for western burrowing owl.
HUMANS			
Aesthetics	X		Structures are significant features on landscape
Flood Damages	X		Substantial downstream damages from flooding from catastrophic dam failure is no action taken
Cost, Sponsor	X		Action will require significant expenditure of funds.
Cost, NED	X		Action will require significant expenditure of funds.
Historic Properties/Cultural Resources	X		Cultural Resources have been identified in the vicinity of the structures.
Environmental Justice	X		Minority and disadvantaged populations are at high risk in the event of a catastrophic failure of the dam if no action is taken
Local and Regional Economy		X	Structures provide flood protection to downstream benefitted area.
Scientific Resources		X	Not Applicable
Potable Water Supply		X	No potable water system within study area.
Public Health and Safety	X		Public Health and Safety is at high risk in the event of a catastrophic failure of the dam if no action is taken
Recreation		X	Opportunities for recreational elements

[1/] Concerns relevant to the proposed action must be considered in the analysis of alternatives

4.0 AFFECTED ENVIRONMENT

This section describes the current physical, biological, ecological, economic, and social environment for the watershed and other areas of the project impact. This provides the context for determining the effects of alternatives. Some conditions will be constant throughout the evaluated life of the project, while others will be subject to change because of social, economic, and political influences.

4.1 CLIMATE

The Sonoran Desert has a continental climate with great variability of both diurnal and seasonal temperatures. It is characterized by a summer monsoon season with light rains in the winter. The average monthly temperatures range from a low of 45.9° F in January to a high of 106.3° F in July. Average monthly rainfall ranges between 0.03 inches in June to 1.01 inches in July, with annual rainfall reaching 6.56 inches in an average year. The Vineyard Road and Rittenhouse Flood Retarding Structures project area elevation ranges between approximately 1,585 to 1,650 feet.

4.2 GEOLOGY

The Powerline, Vineyard Road, and Rittenhouse FRS (PVR) study area is near the junction of the Mexican Highland and Sonoran Desert sections of the Basin and Range physiographic province, just southwest of the boundary between the Basin and Range and Transition Zone physiographic provinces. The boundary between these two provinces is marked by the western edge of the Superstition and Goldfield mountains, which rise abruptly above the valley floor. These mountain ranges also mark the eastern margin of the down-dropped Phoenix Basin, which underlies much of the Phoenix metropolitan area and extends westward to the Sierra Estrella and White Tank Mountains. The Phoenix Basin formed between approximately 8 and 15 million years ago after cessation of the volcanic activity that formed the bulk of the Goldfield and Superstition mountains.

The Phoenix Basin is subdivided into several sub-basins. The study area is within the Mesa-Chandler sub-basin. On the west, this sub-basin is partially separated from the central Phoenix Basin by the bedrock highs of the Tempe Butte area. The Mesa-Chandler sub-basin is bounded by the Goldfield and Superstition mountains on the north and northeast, by Mineral Mountain on the east, and by the Santan Mountains on the southwest.

Alluvial fans and pediments have developed along the Superstition and Goldfield mountain fronts during the last approximately five million years of relative tectonic stability. The pediments are broad, gently sloping erosional surfaces that consist of shallow bedrock covered with a thin veneer of alluvial fan deposits. Bedrock is often exposed in drainages that have cut through the thin alluvial deposits or is exposed in inselbergs (knobs and small hills of bedrock that rise above the alluvial fan surfaces).

Farther west of the mountain fronts, the basin is dominated by a thick sequence of alluvial fan deposits. Alluvial fans are gently sloping masses of alluvium deposited by streams and washes that flow from mountains onto the floor of a valley. As streams emerge from the mountains, they diverge into multiple channels, water begins to percolate into the subsurface, flows diminish and sediment carried by the streams is deposited. Coarser materials (e.g., boulders, cobbles and gravel) tend to be deposited near the apex of fans, whereas finer-grained materials (e.g., sand, silt and clay) are transported to the distal portions of fans. As gradients flatten toward the distal portions of fans, sediments become finer grained and less permeable, and drainage channels often converge.

The Powerline, Vineyard Road, and Rittenhouse FRS have been the subject (particularly Powerline and the northern 1/3 of Vineyard Road FRS) of previous geohazard investigations and analyses including studies as part of this planning study. The Powerline and Vineyard Road FRS are located in a region of local land subsidence. The purpose of the geohazard investigations were to evaluate potential impacts of ground subsidence and earth fissuring on the existing structures and on the selection and subsequent development of rehabilitation designs and/or replacement alternatives for flood protection afforded by the Powerline, Vineyard Road and Rittenhouse Flood Retarding Structures (FRS). The results, findings and conclusion of the studies were used by the project team in its development and evaluation of dam rehabilitation and/or replacement alternatives.

There are known earth fissures in the project area near Hawk Rock and one known earth fissure located immediately downstream of the Powerline FRS embankment at about Station 115+45. There also is a high probability that the earth fissure near Station 115+45 extends beneath the existing embankment. It is suspected that subsidence patterns at the Powerline FRS will continue into the future, potentially causing further development of fissures in this area.

The studies have developed, through various techniques and methods, earth fissure risk zone mapping for the PVR structures. **Figure C-8** in **Appendix C** is the earth fissure risk zones prepared for the PVR structures. As depicted in the risk zone map, Powerline FRS has portions of the dam within all four zones. Vineyard Road FRS is within two zones, and Rittenhouse FRS falls within one zone (the lowest probability zone). The zones are defined below.

In general terms, the earth fissure risk delineating process has evolved to include 4 general earth FRZs that are broadly similar from site to site, although the exact definitions of the FRZs vary from one site to another. The numbering system used to identify the four zones has changed through time and from site to site, so a better understanding of the level of risk is provided by the actual definition than by the zone number. The four FRZ definitions can be summarized as follows:

- Zone 1: An area with a known earth fissure(s), a high probability for the presence of earth fissures without surface expression, or a high probability for the future development of earth fissures.
- Zone 2: An area that in the future is likely to experience tensional ground strain that could cause earth fissures, yet no earth fissures have been identified to date. An area with a moderate probability for the future development of earth fissures.
- Zone 3: An area that has or is likely to experience some tensional ground strain, though not great enough to result in earth fissures. An area with a low to moderate probability for the future development of earth fissures.
- Zone 4: An area that has not, and is not expected to, experience tensional ground strain. An area with a low probability for the future development of earth fissures.

The key terms used in the FRZ definitions are the presence of known fissures or the high, moderate, low to moderate or low probability for the future development of earth fissures.

4.3 SOILS

The soils in the majority of the Vineyard Road and Rittenhouse Flood Retarding Structures watershed are classified by NRCS in hydrologic soil group (HSG) B and D. In the vicinity of the dam the soil is the Mohall loam to Mohall clay loam association (HSG D). At the higher elevations in the watersheds the soils are classified as Gachado-Lomitas-Rock Outcrop to Rock Outcrop (HSG B). The watershed is approximately 10- 20 percent vegetated with desert scrub on flat terrain to desert trees along wash corridors.

4.4 SURFACE WATER

The Vineyard Road and Rittenhouse Flood Retarding Structures controls runoff from a 52.1 and 47.7 square mile drainage area, respectively, that lies east of the dams. The dams receive surface flows from many ephemeral washes. During high flow events the surface water originating from the foothills of the Superstition Mountains collect at the dams and are gradually released to a channel (Powerline Floodway) located at the north end of the Vineyard Road FRS. The Powerline Floodway discharges to the East Maricopa Floodway. Outflows from the dams are conveyed by the principal spillways and the two 300-foot wide Vineyard Road auxiliary spillways and the 600-foot-wide earth-lined auxiliary spillway for Rittenhouse.

Numerous hydrologic surface water evaluations (e.g. rainfall-runoff volumes) have been conducted as part of the planning study for the Powerline, Vineyard Road, and Rittenhouse FRS Rehabilitation or Replacement Project. These evaluations provide the hydrologic basis of the evaluation of existing conditions at the three dams and the basis of evaluation of planning rehabilitation or replacement alternatives. The evaluations were conducted for various storm frequency events, existing and future land use conditions, and planning alternatives.

A summary of the hydrologic and hydraulic evaluations is provided in the “Investigation and Analysis Summary Report” in **Appendix D**. Electronic PDF files of the hydrologic and hydraulic studies and evaluations are provided on the enclosed compact disk (CD).

4.5 WATER QUALITY

The Vineyard Road and Rittenhouse Flood Retarding Structures and watersheds are located in the Arizona Department of Water Resources Phoenix Active Management Planning Area (AMA). The AMA was established pursuant to the 1980 Arizona Groundwater Management Act. The other AMAs include the Santa Cruz AMA, the Tucson AMA, the Pinal AMA, and the Prescott AMA. A review of the on-line Phoenix AMA water database indicates that there are no perennial streams and that there are no impaired lakes or streams located within the watershed. The washes within the watersheds are ephemeral flowing only in response to rainfall events. When flows do occur in the washes, the stormwater runoff typically becomes laden with sediment. This stormwater flows from the watershed into the Vineyard Road and Rittenhouse Flood Retarding Structures FRS impoundments.

The Vineyard Road and Rittenhouse Flood Retarding Structures has no direct effect on water quality in terms of designated beneficial uses, impairment of those uses, or pollutants or parameters that exceed standards.

4.6 WATER CONVEYANCE INFRASTRUCTURE

The Powerline Floodway, discussed in Section 2.1 above, conveys discharges from the principal spillways from both the Powerline FRS and the Vineyard Road FRS. The floodway conveys flows from the dams to the East Maricopa Floodway (EMF). The Powerline Floodway, approximately eight miles long, has a number of side inlets along the length of the floodway to capture and convey offsite flows in addition to the flows from the dams.

The Central Arizona Project (CAP) comprises a 336-mile-long system of aqueducts, tunnels, pumping plants, and pipelines. The CAP is managed and operated by the Central Arizona Water Conservation District (CAWCD). The CAP canal passes through the study area, entering in Apache Junction between Meridian Road and Ironwood Road, running in a south-southeasterly direction approximately parallel to and downstream of the PVR dams. The average width of the canal is 80 feet across.

4.7 SEDIMENTATION

The Watershed Plan summarizes the sedimentation investigation conducted for Vineyard Road and Rittenhouse Flood Retarding Structures. The structures were designed to provide a total cumulative sediment storage capacity of 178 and 175 ac-ft for 50-years of sediment storage.

The Flood Control District of Maricopa County recently completed an updated projected sediment yield estimation for the three dams (*Sediment Yield Estimation for Powerline FRS, Sediment Yield for Vineyard Road FRS, and Sediment Yield Estimation for Rittenhouse FRS, FCD, Dec. 2010*). The District's results indicate a sediment yield of 0.238 ac-ft/mi^2 for Powerline resulting in a 100-year sediment volume of 810 acre-feet. The District's results indicate a sediment yield of 0.272 ac-ft/mi^2 for Vineyard resulting in a 100-year sediment volume of 1,422 acre-feet. The District's results indicate a sediment yield of 0.151 ac-ft/mi^2 for Rittenhouse watershed resulting in a 100-year sediment volume of 641 acre-feet. The District does not have records of actual sedimentation rates. A summary of the sedimentation estimation is provided in the "Investigations and Analysis Report" in **Appendix D**.

For this planning study and based on the previous sediment yield investigations under the original watershed workplans and subsequent studies, design criteria for alternatives that involve a dam rehabilitation a frequency based sediment volume of 100-years was recommended. This would estimate the sediment to a dam rehabilitation alternative (using the District updated sediment yields) of the three structures to be 810 acre-feet, 1,422 acre-feet, and 641 acre-feet for Powerline, Vineyard Road, and Rittenhouse, respectively. This frequency and volumes allow for the potential of future projected sediment being delivered to the structures beyond what is currently being actually recognized and for allowance of accumulation of sediment over time.

4.8 VEGETATIVE COMMUNITY

The project area is within Lower Colorado River Valley Subdivision of the Sonoran Desert Scrub community. The majority of the project area is flat and sparsely vegetated, with the majority of the vegetation occurring along the ephemeral washes. Very dense mesquite bosques, containing velvet mesquite (*Prosopis velutina*), blue paloverde (*Parkinsonia florida*), catclaw acacia (*Acacia greggii),* and cottonwoods (*Populus fremontii*) are present near and adjacent to the FRSs. The mesquite bosques provide valuable food, shelter, and travel corridors for multiple mammal, avian, and reptile species. Additionally, higher plant species diversity was observed within the mesquite bosques. The majority of the mesquites observed within the bosque ranged from 20-30 feet in height. The width of the mesquite bosque ranged from 200 feet to over 650 feet.

The most common plants observed in the upland areas were creosote bush (*Larrea tridentata*) and within and along the washes the velvet mesquite (*Prosopis velutina)* was the dominant plant species. A non-inclusive listing of plant species observed during the "windshield survey" is included in **Table 4** - 1. Multiple grasses (native and non-native), weedy species, and wildflowers were also observed. The overall vegetation cover within the project area is approximately 10-20 percent. However, along the larger washes and within the mesquite bosques, vegetation cover is much higher approximately 60-80 percent.

Table 4 - 1 Non-Inclusive Listing of Vegetation

Common Name	Scientific Name	Comments
velvet mesquite	*Prosopis velutina*	Dominant species washes/near cattle ponds
blue paloverde	*Parkinsonia florida*	Sporadic occurrences
catclaw acacia	*Acacia greggii*	Sporadic occurrences
ironwood	*Olneya tesota*	Sporadic occurrences
Mexican paloverde	*Parkinsonia aculeata*	Isolated occurrence
desert hackberry	*Celtis pallida*	Sporadic occurrences, near large areas of mesquite
Fremont cottonwood	*Populus fremontii*	Two trees observed in southern portion of project area
desert broom	*Baccharis sarothroides*	Common throughout
creosote	*Larrea tridentata*	Dominant species in upland areas
desert globe mallow	*Sphaeralcea ambigua*	Sporadic occurrences
brittle bush	*Encelia farinosa*	Common throughout
barrel cactus	*Ferocactus* spp.	Occasionally observed, more common in southern portion of project area
saguaro	*Carnegiea gigantea*	Occasionally observed.
Arizona grape	*Vitis arizonica*	Associated with mesquite bosques, larger washes, and cattle ponds

4.9 WETLANDS/SIGNIFICANT NEXUS ANALYSIS

Kimley-Horn prepared a Significant Nexus Analysis (SNA) for the PVR FRSs Rehabilitation or Replacement Project (Kimley-Horn, May 2012) in order to determine if the project area contains areas considered jurisdictional by the U. S. Army Corps of Engineers (Corps) under Section 404 of the Clean Water Act (CWA). The SNA was submitted to the Corps of Engineers in June 2012 and the Corps has submitted the SNA to the U.S. Environmental Protection Agency (EPA) in January 2013.

In October 2008, a 6.9-mile reach of the Lower Gila River from Powers Butte to Gillespie Dam was designated a “traditional navigable water” or TNW by the U.S. Army Corps of Engineers (Corps). Therefore, the nearest TNW to the project area is the Lower Gila River from Powers Butte to Gillespie Dam. The project limits consist of the District’s modified easement area (6,237 acres) with the Arizona State Land Department (ASLD), which includes the FRSs, flood pool areas, Powerline Floodway, and maintenance access roads. This SNA includes the project limits and extends to the TNW via the Powerline Floodway, the East Maricopa Floodway (EMF) and Gila River.

The waters analyzed do not significantly affect the chemical, physical, and biological integrity of the downstream TNW, therefore, the waters appear not to be jurisdictional waters of the U.S. Concurrence has not been received by the Corps or EPA as of the date of this report. Further discussion of the SNA is provided in the “Investigation and Analysis Report” in **Appendix D**.

4.10 FISH AND WILDLIFE

Kimley-Horn conducted a Biological Evaluation (BE) study for the PVR FRSs Rehabilitation or Replacement Project and is documented in the report titled “*Powerline, Vineyard Road and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project - Biological Evaluation*” (Kimley-Horn, July 2010) and is summarized in the “Investigation and Analysis Report” in **Appendix D**.

The purpose of the biological evaluation was to document the existing habitat conditions of the project area, and document any species or species specific habitat observed during field biological reconnaissance visits. This assessment focused on gathering general habitat information for the project area and the potential for any threatened, endangered, candidate, or other sensitive species or associated species habitat to occur within the project area.

The majority of the project area is flat and sparsely vegetated, with the majority of the vegetation occurring along the ephemeral washes. Very dense mesquite bosques, containing velvet mesquite (*Prosopis velutina*), blue paloverde (*Parkinsonia florida*), catclaw acacia (*Acacia greggii*), and cottonwoods (*Populus fremontii*) (very rare) are present near and adjacent to the FRSs. The mesquite bosques provide valuable food, shelter, and travel corridors for multiple mammal, avian, and reptile species. Additionally, a higher plant species diversity was observed within the mesquite bosques. The majority of the mesquites observed within the bosque ranged from 20-30 feet in height. The width of the mesquite bosque ranged from 200 feet to over 650 feet. There are no fish in the project area.

4.11 THREATENED AND ENDANGERED SPECIES

The U.S. Fish and Wildlife Service (USFWS) threatened, endangered, proposed, and candidate species lists for Pinal (dated March 5, 2012) and Maricopa (dated January 19, 2012) Counties were reviewed by a qualified biologist to determine species potentially occurring in the project vicinity. A qualified biologist reviewed these lists and determined that no threatened, endangered species or their habitat would be affected by a future proposed project. Suitable habitat is present for the

Tucson shovel-nosed snake (*Chionactis occipitalis klauberi*) and dispersal habitat is present for the Sonoran desert tortoise (*Gopherus agassizii*). These are candidate species that maybe become listed in the future.

The Arizona Game and Fish Department's (AGFD) Heritage Data Management System (HDMS) provided a list of special status species dated April 5, 2012 that have been documented as occurring within three miles of the project area. The AGFD online review tool did list two species of concern: Tucson shovel-nosed snake and pocketed free-tailed bat (*Nyctinomops femorosaccus*). Additionally, the project contains suitable habitat for the western burrowing owl (*Athene cunicularia hypugaea*) which is protected under the Migratory Bird Treaty Act. Therefore, these species are discussed in more detail below. Species included in the USFWS threatened, endangered, proposed, and candidate list but were excluded from further evaluation are provided in the Biological Evaluation Report.

Sonoran Desert Tortoise

The Sonoran desert tortoise is currently listed as a candidate species by the USFWS and will likely be listed as threatened or endangered with critical habitat designated in the future. According to the AGFD the Sonoran desert tortoise is found from northern Sinaloa, Mexico north to southern Nevada and southwestern Utah and from south central California to southeastern Arizona. The Sonoran Desert tortoise is only found south east of the Colorado River while the Mojave population is found north and west of the Colorado River. In Arizona, the Sonoran Desert tortoise occurs primarily on rocky slopes and bajadas of Mojave and Sonoran desert scrub. Adequate shelter is one of the most important habitat features for the Sonoran Desert tortoise. Loose soils are required to excavate burrows, which are typically found under rocks and boulders and occasionally under vegetation. The Sonoran Desert tortoise typically consumes a variety of annual/perennial grasses, forbs, and succulents. According to the AGFD, recently a microhabitat selection study was conducted east of Phoenix on the Florence Military Reservation. Tortoise were found to use gently rolling alluvial fans bisected by desert washes, as opposed to boulder-strewn hillsides, and selected habitat with a higher percentage of vegetative canopy cover. Based on this information, desert tortoises could utilize the project area as dispersal habitat.

Tucson Shovel-Nosed Snake

The Tucson shovel-nosed snake is currently listed as a candidate species by the USFWS and will likely be listed as threatened in the future. The Tucson shovel-nosed snake is found in more productive creosote-mesquite floodplain habitats, with soils described as soft, sandy loams, with sparse gravel at elevations ranging 785 – 1,662 feet above sea level. The project area has suitable habitat throughout, particularly in areas containing ephemeral washes where soils are suitable for burrowing. The snake is known to be present only in Pima and Pinal counties, but a historical record of this species exists in Maricopa County just south of Gila Bend, Arizona.

Pocketed Free-Tailed Bat

The pocketed free-tailed bat is currently listed as a U.S. Forest Service Sensitive species. The pocketed free-tailed bat is found in arid lower elevations usually around high cliffs and rugged rock outcrops. The pocketed free-tailed bat is found in a variety of plant associations including desert shrub and pine-oak forests. Typical roost sites include rock crevices during the day, and may include human built structures. During dry seasons the bat will utilize water sources with open access and a large available surface area to obtain water. Elevation ranges from 190 to 7,520 feet. The project area contains multiple stock tanks which the pocketed free-tailed bat could utilize as a source of water. Suitable prey for the bat is also likely to be present within the project area. However, the project area does not contain any high cliffs, rugged rock outcrops, or human structures which the bat could utilize as roost sites. Therefore, it is unlikely that the pocketed free-tailed bat is present within the project area.

Western Burrowing Owl

The burrowing owl is protected under the Migratory Bird Treaty Act and Arizona State Law, Title 17-101, 235, 236 (USFWS 2003). As defined in the Arizona Game and Fish Departments Burrowing Owl Survey Protocol, suitable habitat for burrowing owl nesting habitat typically consists of dry, treeless, short-grassland or prairie plains. In the desert environment, they nest in areas of short, open scrublands such as mesquite (Prosopis spp.), creosote bush (*Larrea tridentata*), rabbit-brush (*Chrysothanmus nauseous*), and four-wing saltbush (*Atriplex canescens*). Burrowing owls will nest in human-modified landscapes such as: abandoned lots within rapidly developing urban areas, airports, golf courses, agricultural fields, irrigation canals, storm drains, roadsides, and parking lots. In the western United States, burrowing owls do not dig their own burrows, and therefore, depend on the presence of burrowing mammals. The project area does contain suitable habitat for the burrowing owl. The majority of the suitable habitat for the burrowing owl is northeast of the mesquite bosque areas, where there are fewer trees and more open areas.

4.12 Transportation

Major existing transportation corridors near the Powerline FRS, Vineyard Road FRS, and Rittenhouse FRS are Loop 202 (5 miles east of Powerline FRS), US 60 (0.5 mile north of north end of Powerline FRS), Baseline Road (just north of Powerline FRS), and Ironwood Drive (located east of the dams).

Future transportation freeway corridors are currently being planned within the study area by the Arizona Department of Transportation (ADOT). These include State Route 802 and the North-South Freeway. Potential alternative alignments of these freeways cross within the Sponsor's modified easement. Some alignments are shown to cross the actual dam embankment or near the existing auxiliary spillway at Rittenhouse FRS.

4.13 Land Use

The majority of the Vineyard Road and Rittenhouse Flood Retarding Structures watershed is owned by Arizona State Land Department Trust Lands (ASLD) and the US Forest Service (Tonto National Forest). Downstream of the dams is State Trust Lands, CAP (Bureau of Reclamation), and private lands. Land use in the study area upstream of the dams is open desert. Downstream of the dams is open desert, rural residential, master planned subdivisions, and agriculture. Municipalities located near the dams include the City of Mesa and Town of Queen Creek.

Future planning efforts for the vast majority of the surrounding project study area is within the ASLD Superstition Vistas planning area. Superstition Vistas includes approximately 175,000 acres of raw desert land. Scenario B of the Superstition Vistas Scenario Report (East Valley Partnership, 2009) includes the following:

- This (scenario) is designed around multiple pedestrian-friendly, mixed-use areas, concentrated on the transit system and around major roadways. These areas are urban, town and village centers and include attached housing products mixed with retail and employment.
- Due to the breadth of housing choices, the organization of uses, and a sustained effort to catalyze economic development, Scenario B attracts employers and has a better balance of jobs and housing than Scenario A.
- In this scenario, Superstition Vistas would have about the same jobs-to-household ratio as the region as a whole.
- The housing mix is designed to appeal to a broad spectrum of the population to support both workforce and higher-end housing. The housing types offer more choice than those currently under construction in the area. There are more apartments, condos and townhouses, as well as single-family homes. There is also more mixed-use development.
- The transportation system includes commuter rail and light rail, and higher densities are focused around the transit stops. Land uses and transportation networks are designed to facilitate pedestrian, transit, and bicycle travel, rather than just the car. Streets form a connected pattern to disperse traffic and increase transportation efficiency. Many of the new industries are sited along major transportation routes.
- There is greater preservation of the surrounding habitat areas than Scenario A and a somewhat smaller footprint, with less development in the foothills.

4.14 Land Rights and Relocations

The lands in the vicinity of the FRSs are in both private and public ownership. Land Ownership Information (for the downstream area): Private Land – 87%, State/Local 12%, Federal 1%. No land rights acquisitions or relocations are anticipated for this project.

4.15 Important Agricultural Lands

Currently agriculture and rangelands make up a minor percentage of the economic base downstream of the Vineyard Road and Rittenhouse Flood Retarding Structures. Today, crops of cotton and alfalfa are present in the downstream vicinity of the dams. All of the farms downstream of the PVR dams are not considered to be prime farmlands.

4.16 Demographics, Minority, and Disadvantaged Populations

Data on racial and ethnic minority populations for the PVR FRSs Social Population and Demographics Existing Conditions Study (SPDECS) area is provided in the report titled "*Social Population and Demographics Existing Conditions Study for Powerline, Vineyard Road and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project*" (Kimley-Horn, July 2010). The majority of the total population encompassing the Powerline, Vineyard Road and Rittenhouse Flood Retarding Structures (PVR FRSs) area is White which comprises 86.9% of the population. The total minority population is 13.1% with the breakdown of racial and ethnic demographics as follows: Black or African American 1.4%; American Indian and Alaskan Native 1.0%; Asian 1.2%; Native Hawaiian and other Pacific Islander 0.2%; Other 6.6%; Population of Two or More Races/Not Hispanic or Latino 2.8%. The percentages of racial, ethnic and total minority populations appear to be consistent with those of the surrounding communities.

The demographics were conducted on the area defined as the 'Social Population Demographics Existing Conditions Study area' (SPDECS) for the Powerline, Vineyard Road, and Rittenhouse FRSs and documented in the "Social, Population and Demographics Existing Conditions Study" (Kimley-Horn July, 2010). The analysis approach was based on Census Track and Block Groups within and adjacent to the SPDECS study area. The source of the data is the decennial Census 2000 data sets from the United States Census Bureau (Census 2000). The SPDECS study is summarized in **Appendix D –** Investigation and Analysis Report.

The median household income for the PVR FRSs area is between $32,055 and $101,124 for an average median household income of $60,789. This represents a slightly higher median household income than the neighboring communities which range between $33,170 (Apache Junction) and $68,032 (Gilbert) for an average median household income of $58,399.

4.17 Air Quality/Noise/Light

Air Quality

The project area is located within non-attainment areas for the following pollutants: Ozone 8-hour and $PM_{10.}$

Pinal County administers air quality in Pinal County through the Pinal County Air Quality Control District (PCAQCD). The PCAQCD code of regulations (October, 2010) includes construction site rules which would be applicable to construction activities for the PVR project.

Noise

Pinal County noise ordinance is known as the "Excessive Noise Ordinance". The ordinance includes limiting sound levels for land use districts and construction state/stop times for construction of buildings and other projects.

Light

Pinal County has an outdoor lighting code within the County's zoning ordinance which is intended to restrict the permitted issues of outdoor artificial illuminating devices emitting undesirable rays into the night sky. This code includes shielding and filtration requirements and prohibitions on specific lighting types.

4.18 Cultural Resources

A review of NRCS project documentation for the flood retarding structures indicates that there were no known cultural resource considerations during original design and construction of the dams. There are also no known cultural considerations during the repairs of the dams conducted by the NRCS during 1978 to 1991.

A Class III cultural resource survey was completed in December 2009 for geotechnical studies related to the PVR FRSs Rehabilitation or Replacement Project. The survey entitled, Class III Cultural Resources Survey Along the Powerline, Vineyard, Rittenhouse Flood Retarding Structures Between Queen Creek and Apache Junction, Pinal County, Arizona (Jones and Florie 2009) included the results of a “site file check” as well as those of the field survey for the specific geotechnical work that was to be performed. The review area for the PVR FRSs 2009 cultural resource study is a one mile buffer around the PVR FRSs structures.

The 2009 Class III report was prepared in compliance with the National Historic Preservation Act of 1966 (as amended); Arizona State Antiquity laws (A.R.S. § 41-841 et seq); and the State Historic Preservation Act (A.R.S. § 41-861 through § 41-864). The site file check for the review area (including the one mile buffer) that was conducted as a component of that report included site records and project files at the State Historic Preservation Office (SHPO) and the AZSITE cultural resource database. Hereinafter, the site file check component of the 2009 Class III survey effort is referred to as the “2009 cultural resource study”.

Previous Research

The 2009 cultural resource study indicated that at least 59 cultural resource investigations/surveys have taken place within the review area. Most of these previous survey areas are linear in nature and cut across the review area. Nine of these surveys are over 10 years old and therefore would require re-evaluation and resurvey in accordance with SHPO guidance (SHPO Guidance Point No. 5, 2004). Two other investigations were extensive block surveys, conducted for the Lost Dutchman Heights project areas. These surveys covered portions of the review area in the vicinity of the Powerline FRS.

Previously Recorded Cultural Resources

Within the review area there were 72 previously recorded archaeological sites and one archaeological district identified in the 2009 cultural resource study. Though the vast majority of these sites are prehistoric artifact scatters, some with features of habitation sites (approximately 69), there are several historic sites and an archaeological district.

Of the 72 previously recorded sites, seven have been Determined eligible for the National Register of Historic Places (NRHP); 33 are Recommended as eligible for the NRHP; two have been Determined as not eligible; six are Recommended as not eligible; and 24 have not been evaluated. The archaeological district is Recommended as eligible. (Note: Sites “Determined” eligible/not eligible have been evaluated by the SHPO; sites “Recommended” have been evaluated only by their recorder and not the SHPO).

Conclusions and Recommendations

The Sponsor is presently conducting a Class III cultural resources survey for the Area of Potential Effect (APE) for the Preferred Alternative. The purpose of the survey is to conduct a site reconnaissance of the APE for identification and location of cultural resource sites. The completion of the site survey is anticipated in late spring 2013. The cultural resources survey will also identify potential sites that may require mitigation. Mitigation will be conducted in a phased approach prior to construction of the elements of the PVR preferred alternative.

As noted above previous cultural resources surveys and research in the vicinity suggest that there would be a significant number of archaeological sites located within the area of potential effects for the project. Sites in the APE that will not be subject to project-related impacts will be avoided by project implementation activities. Data recovery studies will be performed to mitigate impacts to all sites likely to suffer project-related impacts. Based on known sites in the vicinity, the majority of the cultural resources present would be either prehistoric sites without evidence of habitation (which might include scatters of artifacts on the surface, or artifacts with remnants of just one or a few roasting pits, agricultural features, and/or other non-habitation features) or historical sites (which might include homesteads, farming or ranching features, or simply scatters of historical artifacts). Most of the remaining sites would be smaller prehistoric habitation sites, with up to two relatively large prehistoric habitation sites. Based on experience with recent data recovery efforts in central and southern Arizona, cultural resources mitigation costs have been estimated.

Formal consultation with the Arizona State Historic Preservation Office (SHPO) has been recently initiated following identification of the Preferred Alternative. The initial SHPO consultation correspondence is on file with the NRCS. Consultations with SHPO will continue through the design phase as final alignments, borrow materials, and other disturbance areas are further identified. Formal consultation with Tribal Historic Preservation Offices (THPOs) have recently been initiated following identification of the Preferred Alternative. Consultations with THPOs will continue through the design phase as final alignments, borrow materials, and other disturbance areas are identified.

4.19 Status of Operation and Maintenance

The current *"Operation and Maintenance Agreement" (O&M)* for the Vineyard Road and Rittenhouse Flood Retarding Structures is dated July 14, 1970. The agreement is between the NRCS and the Flood Control District. The Flood Control District is the local Sponsor. The current operation and maintenance activities include annual inspections, crest surveys, sediment and debris removal activities, repair of erosion features, and weed and rodent control/abatement.

4.20 Hazard Classification

The FRSs are designated as a high hazard structures by ADWR and NRCS. High-hazard-potential structures are defined as, "dams located where failure may cause loss of life, serious damage to homes, industrial and commercial buildings, important public utilities, main highways, or railroads." In addition, because of the potential loss of lives and property damage that could occur in the event of failure, the structures were classified by ADWR as an "intermediate" sized structure with a "high-hazard" potential.

4.21 Potential Failure Modes

As noted in the previous section, ADWR and NRCS both classify the Vineyard Road and Rittenhouse FRSs as a high hazard dams with the potential for loss of life if the dams were to suddenly fail. Potential failure modes were identified and qualitatively evaluated in the "*Final Failure Mode and Effects Analysis Report: Cave Buttes Dam, Powerline FRS, Vineyard Road FRS, Rittenhouse FRS, Spook Hill FRS, Signal Butte FRS, and Apache Junction FRS "(KHA, July 2002).* The FMEA identified four Category I and five Category II potential failure modes for Vineyard Road FRS and identified three Category I and six Category II potential failure modes for Rittenhouse FRS. The potential failure modes for each dam are listed below.

4.21.1 *Hydrologic Failure modes*

The July 2002 FMEA identified one hydrologic potential failure mode for each dam. These are:

- Vineyard Road FRS:

  Failure from Overtopping of Dam Crest Due to Very Large Flooding Events Approaching the PMF. (Category I). Hydrologic studies conducted for Powerline, Vineyard, and Rittenhouse FRS indicated there is a potential for Vineyard Road FRS to be overtopped by the full PMF storm event. The overtopping may be on the order of a maximum of 0.45 feet for a total discharge duration of 5.0 hours. As overtopping flows increase erosion of the top of dam crest and downstream slope would then occur leading to an eventual breach of the dam.

- Rittenhouse FRS:

  Failure from Overtopping of Dam Crest Due due to PMF (Category I). Hydrologic studies conducted for Powerline, Vineyard, and Rittenhouse FRS indicated there is a potential for Rittenhouse FRS to be overtopped by the full PMF storm event. The estimated amount of overtopping based on the design crest elevation may be on the order of a maximum of 0.45 feet for a total discharge duration of 5.0 hours. As overtopping flows increase erosion of the top of dam crest and downstream slope would then occur leading to an eventual breach of the dam.

4.21.2 *Structure Failure Modes*

The July 2002 FMEA identified sixteen structure related potential failure modes. These are:

- Vineyard Road FRS (Category I)

  1. Failure from Potential Earth Fissure(s) Through the Dam Embankment in Association With a Significant Flooding Event. The presence of existing earth fissures in the vicinity of Powerline FRS which is adjacent to Vineyard Road FRS demonstrates the possibility for an earth fissure to manifest itself at the Vineyard dam embankment. An earth fissure could cause a structural failure of the embankment by opening a crack through the structure. Alternately the fissure could undermine the dam embankment by abruptly causing separation of the structure at the foundation with the dam bridging the fissure. If the fissure occurred in association with a large flood the structural failure from the fissure would provide a path for a seepage erosion breach. Potentially there will not be a high level of water impoundment during fissure expression. In such case there would be a minimal loss of water.

  2. Failure from Seepage Erosion Through Transverse Cracks Causing Breach of the Dam in Association with a Major Flooding Event. Potential for impounded water to infiltrate and flow into a transverse crack(s) existing in embankment prior to the major flooding event or a transverse crack that develops in association with the flooding. The transverse crack allows the entry of a great enough flow of water to initiate seepage and breaching failure. Generally, the mechanics of the potential failure need to be linearized such that there is an upstream transverse crack(s) or

inflow zone lined-up with a defect in the central filter, which in turn is lined-up with a downstream transverse crack(s).

3. Failure from Seepage Erosion Resulting from a Flow Path Through Foundation and Along the Dam/Foundation Contact. This potential failure mode has three potential failure pathways. Pathways A and B were rated as Category I potential failure modes. Pathway C was rated under Category II. This potential failure mode is initiated by transverse and longitudinal cracks carrying water to foundation in contact with Holocene soils. Path A is initiated by flow into longitudinal and transverse cracks that do not extend through the central filter but do extend to the foundation materials. Path B is initiated through flow into differential settlement cracks. Path C is initiated from flow through remnant upstream borrow areas that potentially have exposed gravels through which a seepage pathway develops through buried channels into the foundation Holocene materials. Generally, the potential failure mode mechanism is a loss of reservoir via the development of erosion/piping tunnel and a subsequent breach of dam via downstream embankment slope collapse.

- Rittenhouse FRS (Category I)

4. Failure from Seepage Erosion Through Transverse Cracks Causing Breach of the Dam in Association with a Major Flooding Event. Potential for impounded water to infiltrate and flow into a transverse crack(s) existing in embankment prior to the major flooding event or a transverse crack that develops in association with the flooding. The transverse crack allows the entry of a great enough flow of water to initiate seepage and breaching failure. Generally, the mechanics of the potential failure need to be linearized such that there is an upstream transverse crack(s) or inflow zone lined-up with a defect in the central filter, which in turn is lined-up with a downstream transverse crack(s).

5. Failure from Seepage Erosion Resulting from a Flow Path Through Foundation and Along the Dam/Foundation Contact. This potential failure mode has three potential failure pathways. Pathways A and B were rated as Category I potential failure modes. Pathway C was rated under Category II. This potential failure mode is initiated by transverse and longitudinal cracks carrying water to foundation in contact with Holocene soils. Path A is initiated by flow into longitudinal and transverse cracks that do not extend through the central filter but do extend to the foundation materials. Path B is initiated through flow into differential settlement cracks. Path C is initiated from flow through remnant upstream borrow areas that potentially have exposed gravels through which a seepage pathway develops through buried channels into the foundation Holocene materials. Generally, the potential failure mode mechanism is a loss of reservoir via the development of erosion/piping tunnel and a subsequent breach of dam via downstream embankment slope collapse.

- Vineyard Road FRS (Category II)

6. Failure From Seepage Erosion Due to Piping Through Foundation. This potential failure mode has three potential failure pathways. Pathways A and B were rated as

Category I potential failure modes and presented above. The Failure Mode from Pathway C is initiated through remnant upstream borrow areas that potentially have exposed coarse materials (e.g. sands and gravels) in contact with reservoir water which provides a seepage pathway through buried channels to Holocene materials in the dam foundation. Generally, the erosion or piping tunnel and subsequent breach of the dam via downstream embankment slope collapse into the erosion tunnel.

7. Failure from Potential Erosion of Abutments during Spillway Discharges. Vineyard Road has two auxiliary spillways – one located at each abutment. The auxiliary spillways are earth-lined limited service spillways. High velocity flows in the spillways could potential erode the abutments of the dam causing loss of reservoir. One erosion process would be direct erosion of the far end of the abutment which forms the approach channel. This embankment is not protected but velocities are less than farther down the spillway. The second erosion process would be erosion of the training dike, which would then allow spillway discharges to begin eroding the abutment of the embankment (which is in effect just the embankment wrapped around to form the spillway channel).
8. Failure from Potential Embankment Slope Instability. Potential embankment slope failure due to internal pressure in the central filter.
9. Failure from Piping Around Principal Spillway and Five Abandoned Irrigation Outlets. Infiltration of water into embankment material around pipe and irrigation outlets and is carried away due to seepage erosion along the pipe or due to piping leading to foundation of an erosional tunnel, caving and formation of a breach failure.
10. Failure from Seepage Erosion Due to Flow/Seepage Erosion Through Animal Burrows. Small animal burrows have been documented in previous inspections and field visits to the dam. The burrows are primarily due to ground squirrels and/or kangaroo rats. The potential failure mode is water impounded on the upstream face of the dam would infiltrate into the animal burrows. The infiltrated water would initiate seepage erosion ultimately leading to an expanded erosion tunnel, collapse of material from above the tunnel and breach of the dam.

- Rittenhouse FRS (Category II)

11. Failure from Potential Erosion of Left Abutment of the Dam During Spillway Discharges. Rittenhouse FRS has one auxiliary spillway – located just to the left of the left abutment of the dam. The auxiliary spillway is an earth-lined limited service spillway. The spillway training wall protects most of the left abutment of the dam. However, the spillway narrows a bit just before its terminus and the training wall ends before reaching the main dam/end of the left abutment. Thus, it is possible that spillway flows could deflect towards the corner of the dam (junction of the left sidewall abutment) and the main (straight) portion of the dam. High velocity flows in the spillway could potentially erode the training wall and the left abutment/main dam causing loss of reservoir.

12. Failure from Potential Earth Fissure(s) Through the Dam Embankment in Association With a Significant Flooding Event. The presence of existing earth fissures nearby (within a few miles of Rittenhouse FRS) demonstrates the possibility for an earth fissure to manifest itself at the dam embankment. An earth fissure could cause a structural failure of the embankment by opening a crack through the structure. Alternately the fissure could undermine the dam embankment by abruptly causing separation of the structure at the foundation with the dam bridging the fissure. If the fissure occurred in association with a large flood the structural failure from the fissure would provide a path for a seepage erosion breach. Potentially there will not be a high level of water impoundment during fissure expression. In such case there would be a minimal loss of water.
13. Failure from Seepage Erosion and Erosion Tunnel Developing Around Gated Irrigation Outlets. Infiltration of water into embankment material around pipe and irrigation outlets and is carried away due to seepage erosion along the pipe or due to piping leading to foundation of an erosional tunnel, caving and formation of a breach failure. Note that a transverse crack could form at the compaction boundary, such a failure process is part of transverse crack failure mode.
14. Failure from Potential Embankment Slope Instability. Potential embankment slope failure due to internal pressure in the central filter.
15. Failure from Seepage Erosion or Piping Due to a Flow Path Through the Foundation. This potential failure mode has three potential failure pathways. Pathways A and B were rated as Category I potential failure modes and presented above. The Failure Mode from Pathway C is initiated through remnant upstream borrow areas that potentially have exposed coarse materials (e.g. sands and gravels) in contact with reservoir water which provides a seepage pathway through buried channels to Holocene materials in the dam foundation. Generally, the erosion or piping tunnel and subsequent breach of the dam via downstream embankment slope collapse into the erosion tunnel.
16. Failure from Seepage Erosion Due to Flow/Seepage Erosion Through Animal Burrows. Small animal burrows have been documented in previous inspections and field visits to the dam. The burrows are primarily due to ground squirrels and/or kangaroo rats. The potential failure mode is water impounded on the upstream face of the dam would infiltrate into the animal burrows. The infiltrated water would initiate seepage erosion ultimately leading to an expanded erosion tunnel, collapse of material from above the tunnel and breach of the dam.

4.22 CONSEQUENCES OF DAM FAILURES

Dambreak analyses were completed by JE Fuller/Hydrology & Geomorphology, Inc. in June 2007 on behalf of the District and LTM Engineering, Inc. The report titled *"Emergency Action Plan for Powerline, Vineyard Road, & Rittenhouse Flood Retarding Structures" (JEF, 2007)* documented the inundation areas downstream from the three dams for emergency spillway discharges and from dambreaks. Copies of the flood inundation mapping from the Emergency Action Plan for Powerline FRS are included in **Appendix C** as **Figures C-16** to **C-19.**

The population-at-risk (PAR) downstream of the Vineyard Road FRS and Rittenhouse FRS was conservatively estimated in the economics study conducted in support of this Plan/EA. The PAR was estimated and documented in the "*Economics Evaluation Technical Memorandum*" (Gannett Fleming, January 2013). The PAR is estimated to be 25,860 people for Vineyard Road FRS and for Rittenhouse FRS is 38,700 people. These estimates are worst case based on simultaneous full occupancy of the commercial buildings, schools, residences, etc. The methodology for determining the PAR is provided in the "Investigation and Analysis Report" provided in **Appendix D** of this Plan/EA.

4.23 AESTHETICS

A Site Analysis for the project study area extending out one mile around the PVR dams was prepared. The Site Analysis identified site constraints and opportunities for the future development of flood hazard mitigation solutions and for potential multi-use functions within the project study area.

Some of the most visually striking and identifiable landforms within the project boundary are the PVR dams themselves. The PVR dams total 11.6 miles in length and have respective maximum heights of 26.1 feet, 16.5 feet, and 24.1 feet. The structures provide 12,036 acre-feet of flood storage and 100-year flood protection for 147 square miles. Recommendations for the rehabilitation of the flood retarding structures (if a rehabilitation alternative is selected) should consider the functioning of the interconnected system, including its three embankments, three reservoirs, four auxiliary spillways, and one floodway (Powerline Floodway).

Atop the FRS dams, spectacular panoramic views are afforded to additional identifiable and noteworthy landforms such as the Superstition Mountains and Tonto National Forest to the northeast, the Usery and Goldmine Mountains to the northwest, and the San Tan Mountains to the southwest. The remaining prevailing landform comprises large, open flat areas, and jagged edged vee-shaped incised drainages that carve into them. The drainages create finger-like patterns overlaying the flat surface of the ground plane.

During the Site Analysis verification site visit, a significant amount of water was observed in the low flow areas within the reservoirs upstream of the dams from a storm event. The dams and associated reservoirs and low flow channels have altered the historic drainage pattern in a way that allows pooling to occur immediately upstream of the dams. This altered drainage pattern created an ideal environment for the formation of a unique mesquite bosque ecosystem immediately upstream of the dams. Careful consideration should be given to future development of land and resource goals and objectives, as well as desired recreation and open space functions to preserve this unique ecosystem to the extend feasible as part of a larger regional habitat corridor. The preservation of the mesquite bosque should also be considered for its potential to serve as an open space amenity and attraction. The significant stand of trees should be considered vegetation of high scenic quality.

The upstream portion of the watershed to the east of the PVR dams is primarily alluvial desert. Land use is predominantly undeveloped land with some urban development occurring along the study area fringes north and west of the PVR dams. In these areas, land use includes agriculture, industrial, and low density housing. The landscape on the upstream side of the dams is unusual for its native Sonoran Desert scrubland context due the lushness provided by the mesquite bosques and pooling in the low flow reservoirs.

The visually dominant dams adjacent to the mesquite bosques constitute another key component of the landscape character. According to the Sponsor's descriptions of methods for providing flood protection for use in scenery and recreation resource assessments of context sensitivity, the structural method employed in this context can be described as a "semi-hard structural method." While the primary objectives of the Sponsor's Policy for Landscape and Aesthetic Treatment of Flood Control Facilities are the preservation of natural landscapes and protection of local community character, flood protection methods vary in their relative ability to complement or enhance the visual character of the landscape setting and achieve context sensitivity.

The panoramic views provided from the tops of the embankments to the surrounding mountains are spectacular. Sponsor's policy is to not allow public access onto the dams. However, where possible, views to the Superstition Mountains and Tonto National Forest to the northeast, views to the Usery and Goldmine Mountains to the northwest, and views to the San Tan and distant mountains to the south should be preserved and focused.

The view sheds as described in this section may be important to traditional (cultural) landscapes. Consultation with appropriate tribes for proposed project input on traditional cultural properties has been initiated.

5.0 ALTERNATIVES

5.1 General

The Vineyard Road and Rittenhouse FRSs are two of three earthen flood retarding structures (Powerline FRS being the third) located east of the Central Arizona Project (CAP) canal. The three structures were originally designed by the NRCS to operate as an integrated system as the principal spillways at Powerline FRS and Vineyard Road FRS both discharge into a common channel – the Powerline Floodway. The Rittenhouse FRS principal spillway discharges into the Vineyard Road FRS flood pool. The result is that all three principal spillways eventually flow into the Powerline Floodway. The “Powerline, Vineyard Road, and Rittenhouse FRSs Rehabilitation or Replacement Project” (Project) was initiated to formulate alternatives to mitigate identified dam safety deficiencies at the three dams. One of the objectives in the formulation of alternatives for the three dams was to maintain the integrated operational relationship of the three dams (or alternatives) to discharge to the Powerline Floodway. This Supplemental Watershed Plan and Environmental Assessment (Plan/EA) presents the alternatives evaluated and preferred alternative for Vineyard Road and Rittenhouse FRSs. The Vineyard Road and Rittenhouse FRSs is a structural plan element of the Williams-Chandler Watershed Work Plan. A separate Supplemental Watershed Plan/EA has been prepared for the Powerline FRS as this dam is a structural element of the Apache Junction-Gilbert Watershed Work Plan.

This section describes the development and formulation of planning alternatives for the Powerline, Vineyard Road, and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project. The formulation of alternatives was developed to meet Sponsor (District) goals and to mitigate or eliminate identified inadequacies associated with the structures.

The primary project goal as defined by the District is to develop an implementable project designed to maintain or improve upon the level of flood protection currently being provided by the PVR FRSs and associated features for the new PVR Project life of 100-years. The Project must meet both District and NRCS requirements for flood protection and must meet District, NRCS and Arizona Department of Water Resources requirements for dam safety.

A secondary project goal is to feasibly minimize the future project “footprint”, the overall land area encompassed by the future flood control features and flood conveyance and flood impoundment land areas, and to identify other potential land uses and activities that are compatible with the safe and proper function, operation and maintenance of the future PVR Project and associated features.

5.2 Formulation Process Preliminary Alternatives

The District, NRCS, and Consulting team held three preferred alternatives selection workshops. These workshops were held on December 8, 2010, April 26, 2011, and April 19, 2012. The purpose of the workshops was to discuss and screen the formulated alternatives and measures. The results of the workshop meetings are summarized in the memorandums for those workshops. Several of the alternatives and measures were screened and determined by the workshop attendees (consisting of the District, NRCS, Arizona State Land Department, and other stakeholder representatives) to be unreasonable because the alternatives were not technically feasible, estimated costs were too excessive compared to other alternatives, an alternative was incorporated or combined with another alternative, and/or did not meet the purpose and need for the project. Note that the alternatives are formulated on a system wide approach (integrated system) such that all three dams were included in an alternative rather than a separate alternative developed for each dam. This system approach was taken to maintain the functional and operational relationship of the three PVR structures. Full descriptions of the alternatives noted below are provided in the "Level I Final Alternatives Summary Report" (KHA, February 2011) and the "Level II Final Alternatives Summary Report" (KHA, June 2012). The alternatives eliminated from further detailed study were screened in the alternatives workshops and documented in the workshop notes (see Appendix C in Level II Final Report for workshop notes and ranking matrices).

The " *Level II Final Alternatives Summary Report*" (Kimley-Horn, June 2012) identified five structural alternatives for plan formulation based on technical analyses and input from the NRCS, the Sponsor, and the Consulting team. These alternatives (alternative numbers are as provided in the Level II report) are listed below for the PVR project:

- Rehabilitation (Alternative 1): Raise and Rehabilitate the Powerline, Vineyard Road, and Rittenhouse FRS structures.
- Combination (Alternative 6): Replace Powerline FRS and Northern 1/3 of Vineyard Road FRS with Basins and Channels, Raise and Rehabilitate the Southern 2/3 of Vineyard Road FRS and Rittenhouse FRS
- Combination (Alternative 6A): Replace Powerline FRS and Northern 1/3 of Vineyard Road FRS with Basins and Channels, Raise and Rehabilitate the Southern 2/3 of Vineyard Road FRS and Convert Rittenhouse FRS to a Levee
- Combination (Alternative 8): Replace Powerline and Rittenhouse FRSs with Channels, Raise and Rehabilitate Vineyard Road FRS
- Combination (Alternative 8A): Replace Powerline FRSs with Channels, Raise and Rehabilitate Vineyard Road FRS, and Convert Rittenhouse FRS to a Levee
- No Action Alternative: Also known as No Action Alternative/Future Without Project

Rehabilitation is defined as modification and improvements of the existing dams to meet current State and Federal dam-safety standards. Rehabilitation would include raising the dams to safely pass the inflow design flood (IDF) through the auxiliary spillways, providing new filters to address potential embankment cracking, providing a hardened dam or channel sections within moderate earth fissure risk zones, modification of auxiliary spillways, and replacing the existing principal spillways.

A combination alternative combines structural measures to replace an individual dam or dam segment with a channel or levee with rehabilitation of the remaining dam structures/embankments. A decommissioning alternative (decommissioning of all three dams) was not selected to be evaluated and nor carried further in the Level II report.

The Level III Analysis included analysis of another alternative – Alternative 8B. The " *Level III Final Alternatives Summary Report*" (Kimley-Horn, September 2012) conducted further evaluations of Alternatives 8A and 8B including refined earthwork quantity and construction costs estimates. Alternative 8B is described in further detail below. The Level III report documents an evaluation of three filter options for dam rehabilitation for the PVR structures. Within Alternatives

8A and 8B, three concept dam rehabilitation filter configurations and two different freeboard levels are evaluated for the rehabilitated/raised Vineyard Road and Rittenhouse FRSs. For the purposes of the Level III report and this Plan/EA, the three dam filter configurations are Option A, Option B and the Hybrid Option. Option A consists of an upstream raise with a sloping filter and new excavated cutoff extended down into competent material. Option B is a symmetrical dam raise with a vertical central filter. The Hybrid Option is a symmetrical raise with a sloping filter from the raised dam crest down to the center of the existing cutoff trench at existing ground. The Hybrid Option then turns to a vertical cement/bentonite cut-off wall through the existing upstream cutoff and into competent material.

Option A, Option B and the Hybrid Option costs were estimated for Rittenhouse FRS as a dam (Alternative 8B), while only Option A and the Hybrid Option costs were estimated for Vineyard Road FRS. Option A includes one foot of freeboard in the quantity calculations and opinion of probable cost. Option B and the Hybrid Option include zero feet of freeboard in the quantity calculations and opinion of probable cost.

Both alternatives are identical in the replacement of Powerline FRS with a new 100-year flood channel. The alternatives differ in the treatment of Rittenhouse FRS (Alternative 8A replaces the dam with a levee, and Alternative 8B rehabilitates the dam) and in the filter treatments for Vineyard Road FRS and Rittenhouse FRS in Alternative 8B. The results of the Level III analysis indicates that Alternative 8A (the 8A option that replaces Powerline FRS with a new channel and hardened channel segments within fissure risk zones; dam rehabilitation for Vineyard Road FRS; and converting Rittenhouse FRS to a levee) was the least cost technically feasible alternative. The Level III report presents and discusses the National Economic Development (NED) alternative as this alternative for the PVR structures. The Level III report also identified the Preferred Alternative as Alternative 8A with the option of hybrid filter for dam rehabilitation of Vineyard Road FRS, replacing Powerline FRS with a 100-year channel, and converting the Rittenhouse FRS to a levee. Therefore, Alternative 8B (and options) with Rittenhouse as a dam was not carried forward for further detailed study in **Section 5.4**.

5.3 ALTERNATIVE PLANS CONSIDERED BUT ELIMINATED FROM DETAILED STUDY

Two alternatives (noted above as Alternative 6 and 8) were developed that incorporated different structural treatments for Rittenhouse FRS as noted above in **Section 5.2**. Alternative 6 and Alternative 6A are described below and differ in the approach for the Rittenhouse FRS. Alternative 6 keeps Rittenhouse as a rehabilitated dam and Alternative 6A modifies Rittenhouse FRS to a levee that discharges into Vineyard Road. FRS. Alternative 8 has three different structural measures, again, relating to the treatment of Rittenhouse FRS. Alternative 8 replaces the dam with a 100-year channel, Alternative 8A replaces the dam with a levee, and Alternative 8B rehabilitates the dam. As noted below, Alternatives 6, 6A, 8, and 8B were eliminated from further detailed study.

The alternatives eliminated from further study are described below along with the reason(s) for elimination. These alternatives are:

Rehabilitation of Powerline, Vineyard Road, and Rittenhouse Flood Retarding Structures (Alternative 1)

The concept for Alternative 1 includes rehabilitating and raising Powerline, Vineyard Road and Rittenhouse FRSs to pass the (planning level) probable maximum flood (PMF), while accounting for estimated future subsidence, one foot of freeboard and sediment storage volume. Powerline FRS will be rehabilitated with an upstream filter in low-moderate fissure risk hazard zones. Segments of Powerline FRS in moderate earth fissure risk hazard zones would be replaced with a hardened dam segment (soil cement core). The Powerline Interim Dam Safety Measure (IDSM) alignment will be maintained but replaced with a hardened dam segment and the crest elevation raised to match the proposed raise on Powerline FRS. Vineyard Road FRS and the remaining portion of Powerline FRS will be rehabilitated with an upstream filter for low-moderate fissure risk hazard zones. Rittenhouse FRS is entirely located in low-moderate fissure risk hazard zones and will be raised and rehabilitated with an upstream filter along the entire length of the structure.

The total opinion of probable construction costs for Alternative 1 ranged from $87,000,000 to $120,000,000. The alternative was eliminated from further evaluation in the workshop conducted on April 19, 2012 due to technical uncertainty of building a dam in an earth fissure prone area.

Decommissioning Powerline, Vineyard Road, and Rittenhouse Flood Retarding Structures by Converting the Dams to Basins (Alternative 2)

The concept for Alternative 2 included reducing the existing structures to non-jurisdictional (by ADWR definition) size with auxiliary spillway heights of six feet. The Powerline IDSM alignment will be maintained for the reduced height Powerline structure. Upstream of the reduced structures, detention basins sized for the 100-year event would be constructed outside of the mesquite bosques to help preserve and protect the bosques. The basins would drain through the bosques and the basin bottom depth will be controlled by the existing principal outlet location. The existing conditions 100-year 24-hour storage volume from the existing conditions 100-year HEC-1 models was used to size each of the basins, in addition to the 100-year sediment volume. No FRS rehabilitation is included.

To evaluate the required excavation volume, the existing flood volume behind the FRS up to the spillway crest height of six feet was used as flood storage and was not included in the volume required for basin excavation. The remaining required storage volume would be provided in the excavated basins where the bottom depth of each basin is controlled by the existing principal outlet location. The basins were sized such that the footprint of each basin was contained within the existing modified easement. The estimated required basin areas and depths without freeboard are 289 acres and ten feet for Powerline, 385 acres and six feet for Vineyard Road, and 538 acres and seven feet for Rittenhouse FRS. The basins will be excavated an additional three feet each in depth to include the 100-year sediment storage.

The opinion of probable cost for converting each FRS to a basin and reducing the dam heights to non-jurisdictional dams (as considered in the Level I analysis) is $190,690,000. This alternative was eliminated from further detailed study in the workshop conducted on April 26, 2011 due to high costs, operational complexity, lower flood protection level (100-year), and handling and storage of excess earthwork spoils.

Decommissioning Powerline, Vineyard Road, and Rittenhouse FRS by Converting all Three Dams to Levees that Drain south to a Basin that Outlets to Queen Creek (Alternative 3).

The concept for Alternative 3 included converting Powerline and Vineyard Road FRSs to levees to meet FEMA and District criteria. Additionally, Rittenhouse FRS would be removed and a levee would be constructed further west and adjacent to the CAP canal. A 100-year detention basin would be constructed at the south end of the project with a gated outlet to Queen Creek Wash.

A new gated at-grade outlet would be constructed at the south end of the 100-year basin to drain the basin to Queen Creek Wash. A new drainage channel would be constructed between the basin outlet and a new CAP overchute near Queen Creek Wash. A gated trash rack would be provided at the new outlet of the basin, and a new basin overflow spillway would be constructed to discharge flow in the same general flowpath as the existing Rittenhouse auxiliary spillway. The Powerline Floodway would not be used under this alternative, but may be utilized as an alternative outlet.

The invert elevation of the CAP overchutes at Queen Creek Wash is approximately 1,566 feet. In comparison, the inverts of the principal spillway outlets at Powerline and Vineyard Road FRSs are 1,563.6 feet and 1,563.8 feet, respectively, lower than the invert elevation of the CAP overchutes at Queen Creek Wash. The low point of the PVR system and the existing CAP overchutes at Queen Creek Wash are separated by approximately 8.5 miles, so even if the overchutes were lowered three feet, the flowpath south to Queen Creek Wash would be effectively flat. The primary constraint of Alternative 3 is achieving positive drainage along the existing structure alignments to drain south to Queen Creek Wash at the new outlet. This is not physically feasible. This alternative was not evaluated further due to the insufficient slope along the existing structures to drain toward the south.

Rehabilitation of Powerline, Vineyard Road, and Rittenhouse Flood Retarding Structures and Excavation of Increased Flood Storage Volume (Alternative 4)

The concept for Alternative 4 includes rehabilitating Powerline, Vineyard Road and Rittenhouse FRSs, and excavating additional storage volume behind the structures sufficient to pass the planning level PMF. Alternative 4 does not include raising the FRSs. The required storage volume excavation will be sufficient to include predicted future subsidence and sediment storage. The Powerline IDSM alignment will be made permanent for Powerline FRS. Powerline and Vineyard Road FRSs would be rehabilitated with an upstream filter for low-moderate fissure risk hazard zones and a hardened soil cement core structure for moderate fissure risk hazard zones. Rittenhouse FRS is entirely located in low-moderate fissure risk hazard zones and would be rehabilitated with an upstream filter along the length of the structure.

The 6-hour planning PMF future conditions HEC-1 models were used to determine the amount of additional flood volume excavation required sufficient for the structure to prevent overtopping. The excavation volume will also include the 100-year sediment volume determined by the District. The stage/storage/discharge curve was updated to reflect the increased volume, and the discharge was adjusted to eliminate overtopping weir flow. The additional storage volume required for Powerline FRS is 7,500 acre-feet. The additional flood storage volumes required for Vineyard Road FRS and Rittenhouse FRS are 11,500 acre-feet and 8,500 acre-feet, respectively. Excavation depths required to achieve these volumes are 28 feet, 20 feet and 20 feet for Powerline, Vineyard Road, and Rittenhouse FRS respectively.

The opinion of probable cost for rehabilitating the FRSs and providing the required flood storage volumes (as considered in the Level I analysis) is $378,203,000. This alternative was eliminated from further detailed study in the workshop conducted on December 8, 2011 due to high costs.

Combination of Decommissioning, New Rittenhouse Structure, and Rehabilitation of Vineyard Road FRS (Alternative 5)

The concept for Alternative 5 includes replacing Powerline FRS and the northern 1/3 of the Vineyard Road FRS with detention basins in low-moderate fissure risk hazard zones and channels in moderate fissure risk hazard zones. The basins and channels would drain to a 100-year basin near the existing shared Powerline FRS and Vineyard Road FRS north auxiliary spillways and outlet to the Powerline Floodway. The southern 2/3 of Vineyard Road FRS would be raised and rehabilitated, and combined with a new Rittenhouse FRS located downstream (west) of the existing Rittenhouse FRS alignment, closer to the CAP canal. The combined structure would be raised to account for predicted future subsidence and sediment storage volume, and share a flood pool with two principal outlets. The Vineyard Road portion of the combined FRS flood pool would drain north to the Powerline Floodway along the existing flow path. The new Rittenhouse portion of the combined FRS flood pool would drain south to Queen Creek Wash. The existing Rittenhouse FRS structure would be removed.

The 6-hour planning PMF future conditions HEC-1 models were used to size the new Rittenhouse/Vineyard Road structure. The 6-hour PMP was updated with the total drainage area for the combined structure. A single HEC-1 model was created combining the full Rittenhouse watershed and the contributing Vineyard Road subbasins. The model was updated with the new PMP and a new stage-storage-discharge curve for the combined structure. The existing 100-year, 24-hour HEC-1 models were used to size the channels and basins for Powerline and the northern 1/3 of Vineyard Road.

There are two primary constraints for Alternative 5. First, the combined Vineyard Road and Rittenhouse FRS would include a new principal spillway that would drain to Queen Creek Wash via a new constructed channel from the southern end of the combined FRS to Queen Creek Wash. The slope of the channel is limited by the invert elevation of the tie-in with Queen Creek Wash. Second, the alternative is also limited by the existing capacity of Queen Creek. The Sonoqui Detention Dike, owned and operated by the CAP, discharges to the existing CAP overchutes at the CAP canal. The major design consideration for a new overchute at Queen Creek Wash is to not adversely impact the capacity and stability of the existing Queen Creek Wash downstream of the CAP canal.

The opinion of probable cost for replacing Powerline FRS and the northern 1/3 of the Vineyard Road FRS with basins and channels, raising and rehabilitating the southern 2/3 of the Vineyard Road FRS and combining the southern 2/3 of the Vineyard Road FRS with a new Rittenhouse FRS as considered in this Level I analysis is $183,952,000. This alternative was eliminated from further detailed study in the workshop conducted on April 26, 2011 due to high costs.

Combination of Decommissioning and Rehabilitation of Vineyard Road and Rittenhouse FRS (Alternative 6)

The concept for Alternative 6 includes replacing the Powerline FRS, the Powerline IDSM, and the northern 1/3 of the Vineyard Road FRS with detention basins in low-moderate fissure risk hazard zones and channels in moderate fissure risk hazard zones. The basins and channels would drain to a 100-year detention basin near the existing shared Powerline FRS/Vineyard Road FRS north auxiliary spillways and outlet to the Powerline Floodway.

The southern 2/3 of the Vineyard Road FRS would be raised and rehabilitated and outlet north towards the Powerline Floodway. The existing Rittenhouse FRS would be raised and rehabilitated and outlet into the Vineyard Road FRS flood pool (as under existing conditions). The southern 2/3 of the Vineyard Road FRS and Rittenhouse FRS would be raised sufficiently to account for estimated future subsidence and sediment storage.

The interconnected basins and channels for Alternative 6 were preliminarily sized using HEC-1 and approximate basin geometry. The trapezoidal channels serve as in-line connections between the basins and are sized to convey routed discharge from 100-year, 24-hour basins to the large detention basin near the existing shared Powerline and Vineyard Road FRS auxiliary spillways. Combination points were inserted at the basin location to determine the required storage volume and the basins were located on existing topography. Channels were sized sufficiently to route flow between the basins. The basins and channels were then input into the FLO-2D models for the alternative. Initially, the dynamic, two-dimensional routing results indicated that the preliminary basin and channel sizes were not sufficient to pass the 100-year, 24-hour event without overtopping. Storage volume and channel capacity were added by iterative trial to provide enough storage volume and channel capacity without overtopping and provide the required one foot of freeboard (or from equation 6.25 from the *DDMMC* if greater than one foot).

The total opinion of probable construction costs ranged from $185,000,000 to $218,000,000. This alternative was eliminated from further detailed study in the workshop conducted on April 26, 2011 due to high costs.

Combination of Decommissioning and Rehabilitation of Vineyard Road, and Converting Rittenhouse FRS to a Levee (Alternative 6A)

The concept for Alternative 6A includes replacing the Powerline FRS, the Powerline IDSM, and the northern 1/3 of the Vineyard Road FRS with detention basins in low-moderate fissure risk hazard zones and channels in moderate fissure risk hazard zones. The basins and channels would drain to a 100-year detention basin near the existing shared Powerline FRS/Vineyard Road FRS north auxiliary spillways and outlet to the Powerline Floodway.

The southern 2/3 of the Vineyard Road FRS would be raised and rehabilitated and outlet north towards the Powerline Floodway. The existing Rittenhouse FRS would be converted to a levee and outlet into the Vineyard Road FRS flood pool. The southern 2/3 of the Vineyard Road FRS would be raised sufficient to account for estimated future subsidence and sediment storage.

The levee is designed to convey the 100-year, 24-hour flood with three feet of freeboard per Federal Emergency Management Agency (FEMA) requirements. The crest elevation varies with an overall levee crest slope of 0.0005 ft/ft. The levee has a 3:1 (H:V) upstream slope and a 2:1 (H:V) downstream slope and a top of crest width of 14 feet. The upstream slope would be treated with erosion protection which consists of rock riprap overlaying a geotextile. The converted Rittenhouse levee was evaluated both in HEC-1 and FLO-2D modeling. The required levee height was determined from the maximum water surface elevation against the FRS embankment along the structure. FLO-2D produced the most conservative results and was used to determine the required crest elevations.

The total opinion of probable construction costs for Alternative 6A ranged from $187,000,000 to $208,000,000. This alternative was eliminated from further detailed study in the workshop conducted on April 26, 2011 due to high costs.

Combination of Decommissioning and Rehabilitation of Vineyard Road, and Converting Rittenhouse FRS to a Levee (Alternative 7)

The concept for Alternative 7 includes replacing Powerline FRS with a 100-year channel draining to Vineyard Road FRS. Vineyard Road FRS would be segmented to raise and rehabilitate the northern ½ of the FRS and convert the southern ½ of the FRS to a levee/ floodway that drains south to Rittenhouse FRS. Rittenhouse FRS would be converted to a 100-year basin that drains to Queen Creek.

The 6-hour planning PMF future conditions HEC-1 model was used to determine the flood volume required for the northern ½ of Vineyard Road. The existing Vineyard Road HEC-1 model was modified to exclude basins no longer contributing to the FRS. The HEC-1 model was updated with a new 6-hour PMP calculation based on the new contributing drainage area.

The 100-year, 24-hour storage volume required for the basin located at the southern ½ of Vineyard Road and Rittenhouse was determined from the existing conditions 100-year HEC-1 models. The total excavation volume required for the basin included the volume of the 100-year sediment storage.

The main constraint for Alternative 7 is achieving positive drainage along the existing structure alignments from Vineyard Road into a Rittenhouse basin that drains to Queen Creek Wash (similar constraint to Alternative 3). Physically, the existing alignment and easement boundary south of Vineyard Road FRS does not permit positive drainage into the Rittenhouse basin, which drains to Queen Creek.

The opinion of probable cost for replacing Powerline FRS with a channel, segmenting Vineyard Road FRS into a raised and rehabilitated FRS for the northern ½ and levee floodway for the southern ½, and replacing Rittenhouse FRS with a basin (as considered in the Level I analysis) is $154,701,000. This alternative was eliminated from further detailed study in the workshop conducted on December 8, 2010 due to high costs.

Combination of Decommissioning Powerline and Rittenhouse FRS and Replacement with Channels and Rehabilitation of Vineyard Road (Alternative 8)

The concept for Alternative 8 includes replacing Powerline FRS and Rittenhouse FRS with 100-year channels to drain to Vineyard Road FRS. Vineyard Road FRS will be raised and rehabilitated sufficient to pass the IDF. Locations where the channel replacing Powerline FRS cross moderate fissure risk hazard zones will require channel defensive mechanisms.

HEC-1 models and the FLO-2D two-dimensional software were used to evaluate the required dam raise elevation. The IDF, future conditions HEC-1 models for the Powerline, Vineyard Road and Rittenhouse watersheds were used to generate hydrographs for inflow points to the FLO-2D model. The IDF was used for Powerline and Rittenhouse channels to account for water in excess of the channel design event that could contribute to Vineyard Road FRS. The FLO-2D model was then used to determine the required dam raise for Vineyard Road FRS to safely pass the IDF.

The proposed Powerline and Rittenhouse channels were sized using existing conditions 100-year, 24-hour peak discharge, as the 24-hour peak discharge was greater than the 6-hour peak discharge. The Powerline watershed features two proposed channels. The first is a collector channel running along the existing FRS alignment to capture inflow that would otherwise reach the structure. The second channel is specifically for Siphon Draw, the largest wash within the watershed.

Channels were initially sized using normal depth routing within HEC-1. The preliminary channel sizes were then input into the alternative FLO-2D model. Where breakouts occurred from channel overtopping, the channel size was increased to provide additional capacity.

The total opinion of probable construction costs for Alternative 8 ranged between $93,000,000, and $118,400,600. This alternative was eliminated from further detailed study in the workshop conducted on December 8, 2010 due to potential impacts to mesquite bosques, lower system performance/flood protection, and relatively higher costs.

Decommissioning by Replacing All Three Structures with In-Line Storage Basins and 100-Year Channel to a 100-Year Basin at Rittenhouse (Alternative 9)

The concept for Alternative 9 includes converting Powerline FRS, Vineyard Road FRS, and Rittenhouse FRS to a stepped 100-year channel with in-line storage basins. The channel will begin in the upper elevations of the modified easement near Powerline FRS and drain south to the low point of the modified easement near Rittenhouse FRS. A new 100-year basin at the southern end of the channel near Rittenhouse FRS would detain the 100-year runoff volume, and drain to Queen Creek Wash through a gated outlet.

A new at-grade principal spillway and a new basin overflow spillway would be constructed at the southern end of the 100-year basin replacing Rittenhouse FRS. The principal spillway would drain south to Queen Creek in a new channel to a new overchute at the CAP canal near the existing outlet of the Sonoqui Detention Dike. An inlet and outlet structure, conduit and trash rack on the inlet would be provided at the new principal spillway. A new basin overflow spillway would be constructed and would drain in the same general flow path as the existing Rittenhouse facility. The Powerline Floodway would not be used under this alternative but could be utilized under a revised alternative scenario.

The upstream invert of the channel is limited by the modified easement boundary in the vicinity of Powerline FRS. The downstream constraint is the elevation of the tie-in with Queen Creek Wash. The upstream and downstream elevation constraints result in an insufficient slope of 0.0006 ft/ft. The combined 100-year, 24-hour discharge for Powerline, Vineyard Road and Rittenhouse is 41,756 cfs, which would require an earthen channel five feet deep with 6:1 side slopes to be over 3,500 feet wide. Given this constraint, further evaluation of this alternative was not considered. This alternative was eliminated from further consideration in the workshop held on December 8, 2010 due to noted technical constraints.

Decommissioning the Powerline, Vineyard Road, and Rittenhouse FRSs with Stabilized Breaches (Alternative 10)

The concept for Alternative 10 calls for decommissioning Powerline, Vineyard Road and Rittenhouse FRSs by constructing stabilized breaches at selected locations at each dam. The structures will be decommissioned by constructing multiple breaches in each structure. The breaches will be designed for the 100-year event and will be located along natural drainage paths in natural washes where existing FEMA 100-year floodplains intersect the structures.

The flow depth and velocities were analyzed at each breach location. Peak flows used in breach analysis were obtained from appropriate combination points in the 100-year, 24-hour existing conditions HEC-1 models. The breaches were analyzed for both concrete and riprap lining. The concrete lining results in high velocities that will require scour protection in the form of riprap or energy dissipaters. Riprap lining results lower-scour exit velocities.

All existing principal spillway and emergency spillway structures would be removed. New 100-year CAP overchutes would be constructed for each breach location. The number of overchute pipes required to pass the 100-year peak discharge over the canal were estimated assuming full flow capacity of the pipes. A pipe diameter of 72-inches was used for overchutes requiring six barrels or less, and concrete rectangular channel overchutes were sized for those requiring more than six barrels.

The opinion of probable cost for decommissioning all three FRSs (as considered in the Level I analysis) is $9,943,000. This alternative was eliminated from further consideration in the workshop held on December 8, 2010 as the alternative did not meet the project purpose and need for continued flood protection.

Rehabilitation of Vineyard Road and Rittenhouse FRS (Alternative 11) (Hybrid filter at Vineyard; Central filter at Rittenhouse)

This alternative would rehabilitate Vineyard Road and Rittenhouse Flood Retarding Structures by raising the dams to safely pass the IDF which is the 6-hr planning PMF, construct new filters, and improve the principal and auxiliary spillways. Vineyard Road FRS would be raised to include stormwater (100 year storm) from the Powerline watershed collected and conveyed by the Powerline Channel to Vineyard and from flows discharged from the rehabilitated Rittenhouse FRS. The operational/system relationship between Vineyard Road FRS and Rittenhouse Road FRS would be maintained under this alternative as presently existing.

HEC-1 models and the FLO-2D two-dimensional software were used to evaluate the required top of dam crest elevation raises. The IDF, future conditions HEC-1 models for the Powerline, Vineyard Road and Rittenhouse watersheds were used to generate hydrographs for inflow points to the FLO-2D model. The IDF was used for the Powerline Channel to account for water in excess of the channel design event (100-year) that could contribute to Vineyard Road FRS. The FLO-2D model was then used to determine the required dam raise for Vineyard Road and Rittenhouse FRS to safely pass the IDF. The required dam raise elevations include estimated subsidence and freeboard.

This alternative for dam rehabilitation of Vineyard Road and Rittenhouse FRS includes construction of a new filter at both dams. Vineyard Road FRS will be rehabilitated with a hybrid combination sloping filter with vertical cement/bentonite cutoff configuration (Hybrid Option).

Rittenhouse FRS will be rehabilitated with a central filter. The filters would extend for the full lengths of the dams and from just below the top of dams to at or below the existing upstream cut-off trench. The existing central filter at Vineyard Road FRS will remain in-place.

The locations of the Vineyard Road FRS north and south auxiliary spillways are maintained and the spillways improved with new structural concrete drop structures. The existing 300-ft wide spillway geometry will be maintained and the north and south spillway crest sections will be raised 4.5 ft and 5.1 ft, respectively, to an elevation of 1580.6 ft.

The new concrete drop structures will be similar to the auxiliary spillway provided at White Tanks FRS No. 3. This structure includes a concrete control spillway weir, downstream concrete apron, and impact blocks for energy dissipation. Rip-rap erosion control blankets are provided at the approach section to the spillway weir and downstream of the impact blocks to control downstream scour.

A controlled low strength material (CLSM) barrier is proposed at the control section for the Rittenhouse FRS auxiliary spillway. The existing 600-ft wide spillway geometry will be maintained and the auxiliary spillway crest elevation will be raised from an elevation of 1598.5 to 1599.8 ft (increase of 1.3 ft). The depth of the CLSM barrier will be two feet below the predicted existing conditions breach depth, the width will be six feet and will span the width of the auxiliary spillway plus additional length to key into training dike embankments.

Alternative 11 would not require any additional right-of-way or easements for the Vineyard Road and Rittenhouse Flood Retarding Structures.

Material would be borrowed to raise the dam crest elevations for both the Vineyard Road FRS and Rittenhouse FRS. This material may be derived from the Powerline Channel excavation (the Powerline Channel is described in the “Powerline FRS Supplemental Work Plan and Environmental Assessment”) or from the flood pool areas of both dams. The material is in the ownership of the Arizona State Land Department. For the purposes of the construction cost any excess material (spoil) would be stockpiled on site within the Sponsor’s easement.

The total opinion of probable construction costs for Alternative11 is $86,683,000 (see cost tables in **Appendix E).** This alternative was eliminated from further detailed study in the Level III report for higher project costs.

Rehabilitation Of Vineyard Road And Rittenhouse FRSs (Alternative 12) (Upstream Sloping Filters)

The concept for this alternative would rehabilitate Vineyard Road and Rittenhouse Flood Retarding Structures by raising the dams to safely pass the inflow design flood (IDF) which is the 6-hr planning PMF, construct new upstream inclined filters, and improve the principal and auxiliary spillways. Vineyard Road FRS would be raised to include stormwater (100 year storm) from the Powerline watershed collected and conveyed by the Powerline Channel to Vineyard and from flows discharged from the rehabilitated Rittenhouse FRS. The operational/system relationship between Vineyard Road FRS and Rittenhouse Road FRS would be maintained under this alternative as presently existing.

HEC-1 models and the FLO-2D two-dimensional software were used to evaluate the required top of dam crest elevation raises. The IDF, future conditions HEC-1 models for the Powerline, Vineyard Road and Rittenhouse watersheds were used to generate hydrographs for inflow points to the FLO-2D model. The IDF was used for the Powerline Channel to account for water in excess of the channel design event (100-year) that could contribute to Vineyard Road FRS. The FLO-2D model was then used to determine the required dam raise for Vineyard Road and Rittenhouse FRS to safely pass the IDF. The required dam raise elevations include estimated subsidence and freeboard.

This alternative for dam rehabilitation of Vineyard Road and Rittenhouse FRS includes construction of a new filter in both dams. The filters are upstream sloping filters extending from the top of dam to at/or below the existing upstream cut-off trench. The existing central filters will remain in place.

The locations of the Vineyard Road FRS north and south auxiliary spillways are maintained and the spillways improved with new structural concrete drop structures. The existing 300-ft wide spillway geometry will be maintained and the north and south spillway crest sections will be raised 4.5 ft and 5.1 ft, respectively, to an elevation of 1580.6 ft.

The new concrete drop structures will be similar to the auxiliary spillway provided at White Tanks FRS No. 3. This structure includes a concrete control spillway weir, downstream concrete apron, and impact blocks for energy dissipation.

A controlled low strength material (CLSM) barrier is proposed at the control section for the Rittenhouse FRS auxiliary spillway. The existing 600-ft wide spillway geometry will be maintained and the auxiliary spillway crest elevation will be raised from an elevation of 1598.5 to 1599.8 ft (increase of 1.3 ft). The depth of the CLSM barrier will be two feet below the predicted existing conditions breach depth, the width will be six feet and will span the width of the auxiliary spillway plus additional length to key into training dike embankments.

Alternative 12 would not require any additional right-of-way or easements for the Vineyard Road and Rittenhouse Flood Retarding Structures.

The construction of the raising and rehabilitation of Vineyard Road and Rittenhouse FRSs embankments potentially locally impacts both environmental and cultural resources. The acres of existing mesquite bosque vegetation that may be directly affected have been quantified. The proposed mitigation would tentatively consist of planting of tall pot plants in locations along the Vineyard Road FRS and Rittenhouse FRS low flow channels. The costs of mesquite bosque mitigation have been included in the alternative cost estimate.

Clearing and construction will temporarily disturb existing vegetation. Disturbed areas will be hydroseeded and restored to a native plant community following construction.

Material would be borrowed to raise the dam crest elevations for both the Vineyard Road FRS and Rittenhouse FRS. This material may be derived from the Powerline Channel excavation (the Powerline Channel is described in the “Powerline FRS Supplemental Work Plan and Environmental Assessment”) or from the flood pool areas of both dams. The material is in the ownership of the Arizona State Land Department. For the purposes of the construction cost any excess material (spoil) would be stockpiled on site within the Sponsor’s easement.

The total opinion of probable construction costs for Alternative12 is $112,160,000 (see cost tables in **Appendix E).** This alternative was eliminated from further detailed study in the Level III report for higher project costs.

5.4 ALTERNATIVES DESCRIPTION

Two alternative plans were identified for detailed study and are noted from this point on as Alternatives 1 and 2.

The four alternative plans are:

- Alternative 1 – No Action Plan/Future Without Project: Vineyard Road and Rittenhouse FRSs remain as currently exists with known inadequacies until Sponsor's eventual Rehabilitation or Replacement of the dams.
- Alternative 2 – Rehabilitation/Decommissioning: Raise and rehabilitate Vineyard Road FRS and convert Rittenhouse Flood Retarding Structure from a dam to a levee. Under Alternative 2, a 'hybrid' filter would be installed at Vineyard Road FRS. The rehabilitation of Vineyard Road FRS will meet current ADWR and NRCS dam safety requirements. The levee will meet current NRCS and FEMA levee safety requirements.

These alternatives are discussed in detail below.

5.4.1 ALTERNATIVE 1 – NO ACTION PLAN/FUTURE WITHOUT PROJECT

The "No Action Alternative" is required under the NRCS National Watershed Manual for a dam rehabilitation planning project. This alternative is also known as the "No Action Alternative/Future Without Project Plan" which is defined as the most likely condition absent the Action Alternatives/Future With Project Plans under current consideration.

Under the "No Action/Future Without Project Alternative" the Sponsor would continue to operate and maintain the Powerline, Vineyard Road, and Rittenhouse Flood Retarding Structures beyond the end of the structures' design lives. The structures would continue to be operated as under existing conditions of the dams with the noted dam safety deficiencies. The structures would continue to have identified safety deficiencies and would not meet current NRCS and ADWR performance standards.

The Sponsor has indicated that without federal financial assistance, sufficient funds are not available to rehabilitate or replace the structures in a timely manner. The Sponsor recognizes, however, that there remains a need to address the existing safety deficiencies. Therefore, the Sponsor would eventually rehabilitate or replace the dams one at a time as non-federal funds become available. The District estimates that rehabilitation/replacement using local funds would occur for the first structure in year 20, the second structure in year 25, and the third structure in year 30 (after the end of the structures design lives).

This alternative is not acceptable to the Sponsor and local community as a viable solution since it does not meet the purpose and need to reduce the risk of loss of life due to catastrophic dam failure. Action is needed to address public health and safety issues surrounding flood control dams that does not meet existing safety and performance standards for a high hazard potential structure. The structures would continue to have safety and performance deficiencies and continue to pose a significant risk of catastrophic failure until eventual rehabilitation or replacement of the structures.

The annual operation and maintenance costs for Alternative 1 were estimated to be $291,700 (see NRCS Table 4 in **Section 8.0**).

5.4.2 Alternative 2 –Rehabilitation of Vineyard Road and Decommission of Rittenhouse FRS/Converting to levee

In Alternative 2, Vineyard Road FRS will be raised and rehabilitated to pass the probable maximum flood (planning level 6-hr PMF), while accounting for estimated future subsidence, freeboard and sediment storage volume. The estimated sediment storage volume included sediment contributing from the Powerline, Vineyard Road and Rittenhouse watersheds. Vineyard Road FRS will be rehabilitated with a hybrid combination sloping filter with vertical cement/bentonite cutoff configuration (Hybrid Option). A plan view of this alternative is provided in **Appendix** C as **Figure C-9**. A typical embankment section showing the hybrid filter of this alternative is provided in **Appendix** C as **Figure C-10**.

HEC-1 models and the FLO-2D two-dimensional software were used to evaluate the required top of dam crest elevation raise for Vineyard Road FRS. The IDF, future conditions HEC-1 models for the Powerline, Vineyard Road and Rittenhouse watersheds were used to generate hydrographs for inflow points to the FLO-2D model. The IDF was used for the Powerline Channel to account for water in excess of the channel design event (100-year) that could contribute to Vineyard Road FRS. The FLO-2D model was then used to determine the required dam raise for Vineyard Road to safely pass the IDF. The required dam raise elevations include estimated subsidence and freeboard.

The existing principal spillway inlet and trash rack at Vineyard Road FRS will be replaced with an NRCS standard riser structure. The pipe size of the existing principal spillway will be increased to meet the NRCS ten day draw down criteria while utilizing the capacity of the Powerline Floodway. United States Department of Agriculture (USDA) SITES version 2005.1.4 software was used to evaluate the Principal Spillway Hydrograph (PSH) to determine the required pipe diameter and auxiliary spillway crest elevations. The PSH analysis for Vineyard Road included the inflow hydrograph from the Powerline Channel watershed, the Vineyard Road watershed and the Rittenhouse watershed. The new pipe outlet diameter is 66-inches and the existing outlet structure will be replaced with a new baffled wall (USBR Type VI) energy dissipator. A plan view of the principal spillway is provided in **Appendix C** as **Figure C-11**.

The locations of the north and south auxiliary spillways are maintained and the spillways improved with new structural concrete drop structures. The existing 300-ft wide spillway geometry will be maintained and the north and south spillway crest sections will be raised 4.5 ft and 5.1 ft, respectively, to an elevation of 1580.6 ft.

The new concrete drop structures will be similar to the auxiliary spillway provided at White Tanks FRS No. 3. This structure includes a concrete control spillway weir, downstream concrete apron, and impact blocks for energy dissipation. A typical section of the auxiliary spillway is provided in **Appendix C** as **Figure C-12**. Rip-rap erosion control blankets are provided at the approach section to the spillway weir and downstream of the impact blocks to control downstream scour.

A plan view of the Vineyard North auxiliary spillway is provided in **Appendix C** as **Figure C-13**. The plan shows a new dam segment/extension of approximately 2,500 feet to tie with the proposed Powerline Channel. A plan view of the Vineyard South auxiliary spillway is provided in **Appendix C** as **Figure C-14**. The plan shows a new dam segment/extension of approximately 500 feet to tie to the Rittenhouse FRS embankment. The training dikes downstream of the auxiliary spillways will be raised and provided with rip-rip for erosion protection.

In Alternative 2, Rittenhouse FRS will be converted to a levee. The existing FRS embankment alignment will remain in place and the embankment height above the required levee height will be excavated and the excavated material placed on the upstream slope. The levee is designed to convey the 100-year, 24-hour flood with 3 feet of freeboard per Federal Emergency Management Agency (FEMA) requirements. The crest elevation varies with an overall levee crest slope of 0.0005 ft/ft. The levee has a 3:1 (H:V) upstream slope and a 2:1 (H:V) downstream slope. The levee crest width will vary from 35 feet to greater than 100 feet. The upstream slope will be treated with erosion protection which consists of rock riprap overlaying a geotextile. A typical cross of the Rittenhouse levee section is shown in **Appendix C** as **Figure C-15.** The converted Rittenhouse levee was evaluated both in HEC-1 and FLO-2D modeling. The required levee height was determined from the maximum water surface elevation against the FRS embankment along the structure. FLO-2D produced the most conservative results and was used to determine the required crest elevations.

The Rittenhouse FRS is currently under the jurisdictional purview of ADWR. To remove the FRS from jurisdictional status would require decommissioning per Arizona Revised Statutes Section 45-1209. The Arizona Administrative Code Section R12-15-1209 Application to Breach or Remove a High or Significant Hazard Potential Dam outlines the requirements to reduce a high or significant downstream hazard potential dam to non-jurisdictional size. These regulations will need to be considered during final design of this alternative.

Alternative 2 would not require any additional right of way or easements for the Vineyard Road Flood Retarding Structure or the Rittenhouse levee.

The raising and rehabilitation of the Vineyard Road FRS and the conversion of the Rittenhouse FRS from a dam to a levee potentially locally impacts both environmental and cultural resources. The acres of existing mesquite bosque vegetation that may be directly affected have been quantified (approximately 105 acres). Mesquite bosque mitigation may include planting new tall-pot mesquite trees (approximately 100 acres) and salvage of some mature mesquite trees and transplanting in designated areas (e.g., along Powerline Channel and potential mitigation area at north end of Vineyard Road FRS, along both Vineyard and Rittenhouse). Mitigation plans will be refined during final design. The estimated costs of mesquite bosque mitigation for the project are $1,218,000.

Clearing and construction will temporarily disturb existing vegetation. Disturbed areas will be hydroseeded and restored to a native plant community following construction.

The cost estimate assumed that the Rittenhouse FRS would be lowered in height for the required levee embankment height. Earth material removed from the embankment would be placed on the upstream slope of the levee. Material would be borrowed to raise the dam crest elevation for the Vineyard Road FRS. This material may be derived from the Powerline Channel excavation (the Powerline Channel is described in the "Powerline FRS Supplemental Work Plan and Environmental Assessment") or from the Vineyard Road FRS flood pool area. The material is in the ownership of the Arizona State Land Department. For the purposes of the construction cost any excess material (spoil) would be stockpiled on site within the Sponsor's easement. Locations of stockpiles would be determined in final design.

An estimation of the potential for impacting cultural resources has been completed for Alternative 2. The area of potential effect (APE) was determined and an estimate of the mitigation for cultural resources prepared. Sites in the APE that will not be subject to project-related impacts will be avoided by project implementation activities. Data recovery studies will be performed to mitigate impacts to all sites likely to suffer project-related impacts. Based on known sites in the vicinity, the majority of the cultural resources present would be either prehistoric sites without evidence of habitation (which might include scatters of artifacts on the surface, or artifacts with remnants of just one or a few roasting pits, agricultural features, and/or other non-habitation features) or historical sites (which might include homesteads, farming or ranching features, or simply scatters of historical artifacts). Most of the remaining sites would be smaller prehistoric habitation sites, with up to two relatively large prehistoric habitation sites within the total APE (for Powerline, Vineyard Road, and Rittenhouse FRSs). Based on experience with recent data recovery efforts in central and southern Arizona, the estimated cost for cultural resources mitigation for the Alternative 2 is $3,010,000.

The installation cost for Alternative 2 is $52,928,300 (see NRCS Table 2 in **Section 8.7**). Total project costs include a contingency of 25%, additional permitting, engineering and construction management percentages.

6.0 ENVIRONMENTAL CONSEQUENCES

This section describes potential effects of the alternatives from **Section 5.4** within each resource category noted as relevant to the proposed action in **Table 3** - 1.

6.1.1 GEOLOGY

The site geology and soils for the north 1/3 of Vineyard Road FRS embankment are subject to land subsidence potentially leading to the development of earth fissures. Earth fissure risk zone mapping has been previously developed for the PVR project. The District has a continuing monitoring program for land subsidence at each of the PVR structures.

Alternative 1 – No Action. This alternative would continue to operate the dams as under existing conditions. The site geology and soils would be a strong concern in Alternative 1 since the north 1/3 of Vineyard Road FRS is within a low-to-moderate earth fissure risk zone and in an area of active land subsidence. Rittenhouse FRS is not located within an earth fissure risk zone nor experiencing active land subsidence.

Alternative 2 – Rehabilitation of Vineyard Road FRS/Decommission of Rittenhouse FRS. This alternative will rehabilitate Vineyard Road FRS and convert Rittenhouse Flood Retarding Structure from a dam to a levee. Alternative 2 would have a short-term effect on soils by soil disturbance/grading activities. The Vineyard Road dam crest elevation would be raised to include anticipated subsidence with the project design life. The site geology and soils would be a moderate consideration for Vineyard Road FRS. The Rittenhouse embankment would be lowered to the 100-year flood level plus 3-feet of freeboard.

6.1.2 PRIME AND UNIQUE FARMLAND

Alternative 1 – No Action. This alternative would have a risk of future catastrophic flooding of important agricultural lands, irrigation canals and diversions.

Alternative 2 – Rehabilitation of Vineyard Road FRS/Decommission of Rittenhouse FRS. This alternative would raise Vineyard Road FRS to safely pass the IDF through the auxiliary spillways. The locations of the auxiliary spillways would not change under this alternative. However, higher flows are designed to pass through the auxiliary spillways than under existing conditions for the IDF. This is a design element for rehabilitation such that no overtopping of the dam will occur under Alternative 2. The Rittenhouse levee would discharge into Vineyard Road FRS and there would be no impoundment at Rittenhouse.

6.1.3 SURFACE WATER QUANTITY

Alternative 1 – No Action. This alternative would continue to operate the dam as under existing conditions. Alternative 1 would does not safely pass the inflow design flood through the auxiliary spillways with the required freeboard.

Alternative 2 – Rehabilitation of Vineyard Road FRS/Decommission of Rittenhouse FRS. This alternative would sufficiently raise Vineyard Road FRS to safely pass the IDF through the auxiliary spillways with the required freeboard. The auxiliary spillways would be improved with stabilized structural control sections and erosion control countermeasures. The Rittenhouse levee would be designed for the 100-year flood invent and would discharge to Vineyard Road FRS. The levee could be potentially overtopped for the PMF event.

6.1.4 Regional Water Management Plans

Alternative 1 – No Action. Alternative 1 would provide continued flood protection up to the 100-year event for downstream canals particularly the CAP canal. The canal would continue to be vulnerable to breach failure the FRSs or overtopping of the structures for storm events approaching the PMF.

Alternative 2 – Rehabilitation of Vineyard Road FRS/Decommission of Rittenhouse FRS. Alternative 2 would provide continued flood protection up to the 100-year event. Overtopping of Vineyard Road FRS would not occur under Alternative 2 as the dam would be raised to safely pass the IDF. The CAP canal would continue be vulnerable flood events greater than the 100-year from flows in the auxiliary spillways. The Rittenhouse levee would be designed for the 100-year event and include 3 feet of freeboard. The levee discharges into the Vineyard Road FRS. The levee could be potentially overtopped for the PMF event placing the CAP canal at risk.

6.1.5 Floodplain Management

Alternative 1 – No Action. Alternative 1 would provide continued flood protection up to the 100-year event for the downstream floodplain.

Alternative 2 – Rehabilitation of Vineyard Road FRS/Decommission of Rittenhouse FRS. This alternative would have a long-term beneficial direct effect by reducing the risk of flooding on the downstream floodplain event by providing effective flood control up to the 100-year event. The Federal Emergency Management Agency (FEMA) floodzone Zone A designations could be removed from the floodplain maps.

6.1.6 Threatened and Endangered Species

Alternative 1 – No Action. This alternative will have no direct effect on special status fish or wildlife or their habitats.

Alternative 2 – Rehabilitation of Vineyard Road FRS/Decommission of Rittenhouse FRS. A qualified biologist determined that federally threatened and endangered species or critical habitat would not be potentially impacted by this alternative since suitable habitat for these species is not present in the project area.

Suitable habitat is present for the Tucson shovel-nosed snake (*Chionactis occipitalis klauberi*) and dispersal habitat is present for the Sonoran desert tortoise (*Gopherus agassizii*). These are candidate species for the U.S. Fish and Wildlife Service (USFWS) and may become listed in the future and warrant additional assessment.

Survey protocol for the Tucson shovel-nosed snake has not been published by the USFWS. Prior to construction the status of the Tucson shovel-nosed snake on the USFWS threatened, endangered, proposed, and candidate list will be re-verified (i.e. status changed from candidate to threatened) and coordination with the USFWS will be undertaken to determine if a survey protocol has been established and/or if a survey is required. If this species is observed construction will cease until measures can be taken to ensure the preservation of the snake and/or its habitat.

Desert tortoise has the potential to occur within the project area. Prior to start of construction, the project area will be canvassed for tortoises and, if any tortoises are discovered, Arizona Game and Fish Department (AGFD) Guidelines for Handling Sonoran Desert Tortoises Encountered on Development Projects (Revised October 23, 2007) will be followed.

Additionally, the project contains suitable habitat for the western burrowing owl (*Athene cunicularia hypugaea*) which is protected under the Migratory Bird Treaty Act. Prior to start of construction, a survey for burrowing owls will be required in the disturbance area following the AGFD protocol (January 2009).

As a result of the actions described above, there will be no effect on federally threatened and endangered species or their critical habitat due to implementation of this alternative. The above-mentioned mitigation measures will be utilized to minimize impacts to special status species.

6.1.7 Vegetative Communities

The biotic community within the study area is identified as the Arizona Lower Colorado River Valley, Sonoran Desert Scrub community. Vegetation is found throughout the FRSs and study area and consists primarily of woody shrubs and herbaceous growth.

Alternative 1 – No Action. This alternative has no effect on vegetation communities and allows the continued presence of the mesquite bosque upstream of the dams.

Alternative 2 – Rehabilitation of Vineyard Road FRS/Decommission of Rittenhouse FRS. Clearing and excavation for dam rehabilitation and O&M access roads for the dam and levee will disturb existing vegetation. Disturbed area will be hydroseeded following construction. Mitigation measures would be implemented to reduced short term and long term impacts. The acres of existing mesquite bosque vegetation that may be directly affected by construction activities have been quantified (approximately 105 acres). Mesquite bosque mitigation may include planting new tall-pot mesquite trees (approximately 100 acres) and salvage of some mature mesquite trees and transplanting in designated areas (e.g., along Powerline Channel and potential mitigation area at north end of Vineyard Road FRS, along both Vineyard and Rittenhouse). Mitigation plans will be refined during final design. The estimated costs of mesquite bosque mitigation for the project are $1,218,000.

6.1.8 Fish and Wildlife Habitat

The arroyos upstream of the dams are normally dry except during heavy rainfall events and do not support fish populations. This local desert environment is home to several species of birds, reptiles, and mammals that use scrub desert habitat.

Alternative 1 – No Action. This alternative will have no direct effect on fish or wildlife or their habitats.

Alternative 2 – Rehabilitation of Vineyard Road FRS/Decommission of Rittenhouse FRS. There will be no direct effect on fish by Alternative 2. Wildlife species present in the study area could have a short-term direct effect by Alternative 2. Wildlife would also be disturbed by construction activities and would likely move away from the construction area. This effect would be short-term during construction. Wildlife would likely move back into the construction area as soon as construction is completed. The loss of vegetation would also be a short-term temporary loss of habitat as disturbed areas will be hydroseeded following construction. The removal of trees would be minimized and/or mitigated. Implementation of this alternative will impact the existing mesquite bosque. Mitigation measures, as described above, would be implemented to reduce short term and long term impacts.

6.1.9 *Migratory Birds/Bald and Golden Eagles*

Alternative 1 – No Action. This alternative has no effect on migratory birds/bald and golden eagles.

Alternative 2 – Rehabilitation of Vineyard Road FRS/Decommission of Rittenhouse FRS. The project area contains suitable habitat for the western burrowing owl (*Athene cunicularia hypugaea*) which is protected under the Migratory Bird Treaty Act. Prior to start of construction, a survey for burrowing owls will be required in the disturbance area following the AGFD protocol (January 2009). Mitigation measures will be completed as part of final design.

6.1.10 Aesthetics

Alternative 1 – No Action. This alternative would have no effects on aesthetics. The project area would remain as it is currently with existing conditions.

Alternative 2 – Rehabilitation of Vineyard Road FRS/Decommission of Rittenhouse FRS. The construction activities for this alternative would raise and rehabilitate the Vineyard Road FRS and convert the Rittenhouse FRS to a levee by lowering the dam crest elevation and conveying flows from Rittenhouse to the Vineyard Road FRS flood pool. This alternative would have a beneficial impact on the landscape by lowering the profile of an existing dam (Rittenhouse FRS converted to a levee) but a negative impact to the local landscape over existing conditions by raising the height of an existing dam (Vineyard Road FRS). Any excess spoils materials would be stockpiled within the Sponsor's easement.

6.1.11 Flood Damages

Alternative 1 – No Action. This alternative would have a long-term adverse direct effect by allowing the continued risk of flood damages to downstream homes, businesses, and infrastructure from a catastrophic flood event.

Alternative 2 – Rehabilitation of Vineyard Road FRS/Decommission of Rittenhouse FRS. This alternative would have a long-term beneficial direct effect by reducing the risk of flood damages to homes, businesses, and infrastructure from a catastrophic flood event by raising and rehabilitation of the Vineyard Road FRS and eliminating the impoundment at Rittenhouse FRS and providing effective flood control up to the 100-year event.

6.1.12 Historic Properties/Cultural Resources

Alternative 1 – No Action. This alternative would have no effect on historic properties/cultural resources.

Alternative 2 – Rehabilitation of Vineyard Road FRS/Decommission of Rittenhouse FRS. Previous cultural resources surveys and research in the vicinity suggest that there may be several archaeological sites located within the area of potential effects (APE) for the alternative. Sites in the APE that will not be subject to project-related impacts will be avoided by project implementation activities. Data recovery studies will be performed to mitigate impacts to the sites likely to suffer project-related impacts. Based on known sites in the vicinity, the majority of the cultural resources present would be either prehistoric sites without evidence of habitation (which might include scatters of artifacts on the surface, or artifacts with remnants of just one or a few roasting pits, agricultural features, and/or other non-habitation features) or historical sites (which might include homesteads, farming or ranching features, or simply scatters of historical artifacts). Most of the remaining sites would be smaller prehistoric habitation sites, with up to two relatively large prehistoric habitation sites. Based on experience with recent data recovery efforts in central and southern Arizona, cultural resources mitigation costs have been estimated for this alternative.

6.1.13 Environmental Justice

Alternative 1 – No Action. This alternative would have a risk of future catastrophic flooding that would affect the health and safety of minority or disadvantaged populations.

Alternative 2 – Rehabilitation of Vineyard Road FRS/Decommission of Rittenhouse FRS. This alternative would raise Vineyard Road FRS to safely pass the IDF through the auxiliary spillways. The locations of the auxiliary spillways would not change under this alternative. However, higher flows are designed to pass through the auxiliary spillways than under existing conditions for the IDF. This is a design element for rehabilitation such that no overtopping of the dam will occur under Alternative 2. The Rittenhouse levee would discharge into Vineyard Road FRS and there would be no impoundment at Rittenhouse. The construction project could generate short-term jobs for local workers.

6.1.14 Public Health and Safety

Alternative 1 – No Action. This alternative would have a long-term adverse direct effect by allowing the continued risk to human health, safety, and loss of life from a catastrophic flood event.

Alternative 2 – Rehabilitation of Vineyard Road FRS/Decommission of Rittenhouse FRS. This alternative would have a long-term beneficial direct effect by reducing the risk to human health and safety from a catastrophic flood event by raising the Vineyard Road FRS to safely pass the IDF through the auxiliary spillways. Rittenhouse levee would be designed for the 100-year flood event with three feet of freeboard. This alternative would eliminate the impoundment at Rittenhouse FRS.

6.1.15 Cumulative Impacts

The cumulative impacts of the proposed project were considered during planning. The planning team considered proposed actions as outlined in the adjacent Apache Junction-Gilbert Watershed for the Powerline FRS as well as other known and foreseeable proposed actions by other state or federal agencies. The team determined that the cumulative impacts of the proposed actions in this watershed and the Apache Junction-Gilbert Watershed for the Powerline FRS will have an overall beneficial impact for the people and resources of the area. The team determined that there are no other proposed actions in the project area that will have potential adverse impacts. The Arizona Department of Transportation (ADOT) is currently planning potential freeway alignments which may impact the project area. The project sponsor will continue to coordinate with ADOT to minimize any adverse impacts as planning proceeds.

6.2 Comparison of Alternative Plans

This section describes the extent to which each alternative meets the project purpose of flood prevention and the Sponsor's formulation goal to provide for continued flood protection while meeting all of the standards set by ADWR and the NRCS for safety and reliability of the project. Also presented are risks and uncertainty associated with the alternatives.

Alternative 1 (No Action), the Vineyard Road and Rittenhouse Flood Retarding Structures would remain in place and would continue to provide flood protection up to the 100-year event, given assumed future conditions on the upstream watershed to be the same as existing conditions, until year 2018 and 2019, respectively (end of design life). The Vineyard Road and Rittenhouse Flood Retarding Structures would not meet all of the standards set by ADWR and the NRCS for public safety and reliability. The previously described inadequacies in auxiliary spillway capacity, and embankment cracking would remain. At the end of the design life period, the Sponsors would continue to operate and maintain the dams until such time that available construction funding becomes available to replace the dams. Therefore, Alternative 1 is not acceptable to the Sponsor and local community as a viable solution since it does not meet the purpose and need to reduce the risk of loss of life due to catastrophic dam failure. The structures would continue to have safety and performance deficiencies and continue to pose a significant risk of catastrophic failure until eventual rehabilitation or replacement of the structures. The Sponsor has indicated rehabilitation may occur in year 20 and year 30 for Vineyard Road FRS and Rittenhouse FRS, respectively, after this Supplemental Watershed Plan/EA is promulgated.

Alternative 2 rehabilitates Vineyard Road FRS to meet or exceed current ADWR and NRCS dam safety criteria. The Vineyard Road FRS would be rehabilitated with the installation of a 'hybrid' filter. The dam is designed to provide flood protection for greater than the 100-year storm event and to safely pass the IDF (which is the 6-hr PMF). Alternative 2 converts the Rittenhouse FRS from a dam to a levee designed for the100-year event plus 3 feet of freeboard. The levee would meet FEMA and NRCS levee safety criteria. There would be no impoundment at Rittenhouse and the flows from the levee would discharge to the Vineyard Road FRS. Therefore, Alternative 2 meets the project purpose and the Sponsor's formulation goal.

6.2.1 Risk and Uncertainty

A variety of factors contribute to the potential for flood control structure failure, including storm event intensity, control structure construction materials and techniques, and operation and maintenance activities. Many of the uncertainties described below will be addressed during the design phase of the project.

Existing Condition

Under Alternative 1 – No Action, the Sponsor (District) would continue to operate and maintain the dams in their present condition and in accordance with the current Emergency Action Plans. The dams would continue to have inadequacies in auxiliary spillway capacity. As a result, there is a risk of overtopping and/or dam break until the FRSs are rehabilitated or decommissioned.

Geohazard Investigations and Monitoring

The northern 1/3 of Vineyard Road FRS is located in an area of known active land subsidence. There is uncertainty in whether an earth fissure will be expressed at the north 1/3 of Vineyard Road FRS. The District has a continuing land subsidence monitoring program to provide data and information over time for local land subsidence. The northern 1/3 of Vineyard Road FRS is located south of Powerline FRS, a dam which is in an area with a known earth fissure in close proximity to the dam.

Hydrology and Hydraulics

Current hydrologic analytical results indicates both the dams and auxiliary spillways are not capable of passing the planning 6-hr PMF (for both existing and future land use conditions), which overtops the dams. This presents a risk of potential overtopping of the dams.

Vineyard Road FRS experiences flow in the south auxiliary spillway for the 500-year, 24-hour existing conditions storm event at a depth of 0.5 ft. The 500-year, 24-hour event is the only existing conditions auxiliary flow for Vineyard Road FRS. The future conditions land use 100-year, 24-hour event for Vineyard Road results in a flow depth of 0.6 ft in the south auxiliary spillway. The future conditions land use 500-year, 24-hour event results in a flow depth of 1.8 ft in the south auxiliary spillway and 1.2 ft in the north auxiliary spillway. The future conditions "with retention" land use for Vineyard Road FRS results in no auxiliary spillway flow for the 100-year, 6-hour or 100-year, 24-hour events.

Rittenhouse FRS experiences flow in the auxiliary spillway for the 500-year, 24-hour existing conditions storm event at a depth of 1.0 ft. The 500-year, 24-hour event is the only existing conditions auxiliary flow for Rittenhouse FRS. The future conditions land use 100-year, 24-hour event for Rittenhouse FRS results in a flow depth of 0.6 ft in the auxiliary spillway. The future conditions 500-year, 24-hour event results in a flow depth of 1.9 ft in the auxiliary spillway. The future conditions land use "with retention" results in no flow for the 100-year 6-hour or 100-year 24-hour events. The future conditions "with retention" land use for Rittenhouse FRS results in no auxiliary spillway flow for the 100-year, 6-hour or 100-year, 24-hour events.

The erosion analyses using the SITES model for Vineyard Road FRS indicates that the south auxiliary spillway erodes during the stability design hydrograph and both spillways breach during the existing and future conditions freeboard design hydrographs. The erosion analyses using the SITES model for Rittenhouse FRS indicates that the auxiliary spillway breaches during the existing and future conditions freeboard design hydrographs.

<u>Alternative – Rehabilitation/Decommissioning</u>

The proposed alternatives developed in this study are subject to uncertainty because of missing or approximate information. Uncertainties and the effects of these uncertainties, and suggestions for future studies are listed below.

Geohazard Investigations and Monitoring

The northern 1/3 section of Vineyard Road FRS is located within an earth fissure risk zone (low-to-moderate). Previous planning alternatives for this segment of Vineyard Road FRS included providing a hardened dam section as a risk reduction measure for a potential earth fissure. Subsequent engineering evaluation eliminated the need for a hardened dam section. The future projection of the delineation of the risk zones and level of risk zone could potentially change during the design life (100-years) of the proposed project. Continued monitoring of land subsidence and geo-hazard investigations are recommended for the design life of the project for Vineyard Road and Rittenhouse FRSs.

Embankment Filters

Optional filter configurations have been conceptually evaluated and presented in the report titled "*Final Filter Alternatives Memorandum*" (AMEC, May 2012). The three filters options are: central filter, hybrid filter, and an upstream sloping filter. Initial cost estimates of the central filter and the hybrid filter shows that these two filter types are more economical compared to the upstream sloping filter. The concept of the hybrid filter is provided in **Appendix C** as **Figure C-10**.

Alternative 2 proposes a new embankment filter for Vineyard Road to mitigate for transverse and longitudinal cracking (and other potential failure modes). A 'hybrid' filter is proposed for Vineyard Road FRS.

The hybrid filter was carried forward as the Sponsor's preferred option (Alternative 2) as the concept mitigated for the identified embankment/structure potential failure modes. The central filter and upstream sloping filter were not carried forward as there remains uncertainty in addressing all embankment/structure potential failure modes, constructability issues, and construction costs.

For the purposes of the National Economic Development analysis, the hybrid filter was carried forward as potentially the least-cost viable option (Alternative 2). Part of the Sponsor's final decision making on filter selection will be the ADWR permitting and approval.

Construction Sequence

The construction of the rehabilitation of Vineyard Road FRS needs to occur first. The system operational relationship between the PVR structures are that both the Powerline Channel (described in a separate document titled "*Draft Supplemental Watershed Plan and Environmental Assessment for the Powerline FRS*" by Kimley-Horn, January 2013) and the Rittenhouse levee flows are conveyed to the Vineyard Road FRS. The dam rehabilitation improvements for Vineyard Road FRS include/provide for flood storage capacity from the Powerline watershed and the Rittenhouse watershed for the 100-year flood event. The next structure to be constructed should be the elements of the Powerline Channel, followed by the Rittenhouse levee.

Hydrology and Hydraulics

The SITES modeling for the principal spillway hydrograph (PSH), stability design hydrograph (SDH), and integrity or freeboard hydrograph (FBH) was completed for the existing conditions as part of this planning study. SITES modeling was completed for the alternatives (8A and 8B) to ascertain the volume and peak discharge contributing from the Powerline watershed and Rittenhouse watershed to the Vineyard Road FRS. PMF modeling was conducted using HEC-1 and FLO-2D to estimate the contribution from the Powerline and Rittenhouse watersheds to the Vineyard Road FRS. However, SITES hydrologic and spillway erosion modeling was not completed for the alternatives for the SDH or the FBH. These need to be completed as part of final design to determine the final Vineyard Road FRS flood volume storage and assist with design of the auxiliary spillways for Vineyard Road FRS.

This study developed a 'planning PMP' which is a reduced precipitation depth over the Hydrometerological Report 49 (HMR-49) derived precipitation depths. The report titled "*Powerline, Vineyard Road and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project – Final PMP Technical Memorandum*" (Kimley-Horn, July 2010) recommended a ten percent (10%) reduction of the HMR-49 derived 6-hr PMP as the planning PMP for analysis of the operational response of the existing dams and for the proposed alternatives. The recommendation was based on a site-specific PMP study conducted for the Magma FRS (another flood retarding structure located south of the Rittenhouse FRS).

The Arizona Department of Water Resources is currently developing updated PMP maps for the State of Arizona. These maps should be used as part of final design to conduct a site-specific PMP study for the PVR watersheds to confirm the planning PMP reduction and/or determined if a further reduction may be warranted. The new site-specific PMP values should be used to update the IDF hydrology and hydraulics for the PVR watershed and structures.

Auxiliary Spillways

Initial SITES erosion modeling indicates that all three existing auxiliary spillways (north and south auxiliary spillway for Vineyard Road FRS and the auxiliary spillway for Rittenhouse FRS) will breach during the PMF event. The erosion modeling was based on limited subsurface profiling of the spillways and conservative SITES modeling parameters. To mitigate for potential breach and headcutting through the auxiliary spillway control sections, Alternative 2 includes providing stabilized control sills and erosion countermeasures for the auxiliary spillways.

Under Alternative 2 for Vineyard Road FRS, the locations of the north and south auxiliary spillways are maintained and the spillways improved with new structural concrete drop structures. The existing 300-ft wide spillway geometry will be maintained and the north and south spillway crest sections will be raised.

The new concrete drop structures will be similar to the auxiliary spillway provided at White Tanks FRS No. 3. This structure includes a concrete control spillway weir, downstream concrete apron, and impact blocks for energy dissipation. A typical section of the auxiliary spillway is provided in **Appendix** C as **Figure C-12.** Rip-rap erosion control blankets are provided at the approach section to the spillway weir and downstream of the impact blocks to control downstream scour.

A plan view of the Vineyard North auxiliary spillway is provided in **Appendix C** as **Figure C-13**. The plan shows a new dam segment/extension of approximately 2,500 feet to tie with the proposed Powerline Channel. A plan view of the Vineyard South auxiliary spillway is provided in **Appendix C** as **Figure C-14**. The plan shows a new dam segment/extension of approximately 500 feet to tie to the Rittenhouse FRS embankment. The training dikes downstream of the auxiliary spillways will be raised and provided with rip-rip for erosion protection.

Final design spillway hydraulics and SITES erosion modeling will provide better detail to design the structural auxiliary spillways.

FEMA Floodplains

The Rittenhouse levee will be designed for the 100-year storm event and will discharge into the Vineyard Road FRS. The levee will be designed to meet or exceed FEMA, District, and NRCS design requirements for levees/dikes. The existing FEMA floodplain mapping indicates several washes with Zone A floodplains. The Rittenhouse levee will intercept these washes and remove the Zone A floodplain downstream of the levee. For the levee to be recognized as providing 100-year flood protection a FEMA CLOMR/LOMR should be prepared.

Cultural Resources

Previous cultural resources surveys and research in the vicinity suggest that there would be a number of archaeological sites located within the area of potential effects (APE) for the alternative. Sites in the APE that will not be subject to project-related impacts will be avoided by project implementation activities. Cultural resource surveys are currently underway for the APE and will be completed prior to final design. Data recovery studies will be performed to mitigate impacts to the sites likely to suffer project-related impacts. Based on known sites in the vicinity, the majority of the cultural resources present would be either prehistoric sites without evidence of habitation (which might include scatters of artifacts on the surface, or artifacts with remnants of just one or a few roasting pits, agricultural features, and/or other non-habitation features) or historical sites (which might include homesteads, farming or ranching features, or simply scatters of historical artifacts). Most of the remaining sites would be smaller prehistoric habitation sites, with up to two relatively large prehistoric habitation sites. Based on experience with recent data recovery efforts in central and southern Arizona, cultural resources mitigation costs have been estimated for this alternative.

6.2.2 NED, EQ, and OSE Accounts

The requirements under “Economic and Environmental Principles and Guidelines (“P&G”) for Water and Related Land Resources Implementation Studies” (WRC 1983) have been applied to the current study and have been used in planning this action. Principles and Guidelines specify methodology for calculating economic effects and for evaluating and displaying social and environmental factors in a format unique to P&G. It includes requirements for scoping, public participation, and equal treatment of all alternatives that are equivalent to those for the National Environmental Policy Act (NEPA).

Principles and Guidelines established four accounts to summarize both positive and negative effects of water projects: the National Economic Development (NED) account, the Environmental Quality (EQ) account, the Other Social Effects (OSE) account, and the Regional Economic Development (RED) account. The accounts describe impacts to various elements of the natural and human environment, described explicitly above, and summarize relationships between other elements of NEPA, such as the relationship between short-term use of resources (e.g. land, limited public funds, etc.) and maintenance of long-term productivity (e.g. improved flood protection). The NED, EQ, and OSE accounts are discussed below. The RED is not a requirement under P&G and was not considered in this study.

The effects of the alternative plans in terms of the NED account are summarized in **Table 6 - 1** and **6-1-A** for Vineyard Road FRS and Rittenhouse, respectively. The project investment cost includes the construction cost, mobilization, contingencies, engineering and design, supervision and administration, construction surveying, and stormwater pollution prevention plan.

Table 6 - 1 Summary and Comparison of Candidate Plans – NED Account (Vineyard Road FRS)

	Alternative 1 No Action	Alternative 2 Preferred/NED Rehabilitation/ Decommissioning
Project Investment	$248,900 (O&M)	$43,612,200
Beneficial Annual[1/]	$0	$0
Adverse Annual (Project costs and maintenance)	$248,900	$1,697,600
Net Beneficial	($248,900)	$(1,697,600)

[1/] The proposed project will provide an estimated $182,400 and $4,021,700 in average annual equivalent damage reduction benefits at Vineyard FRS and Rittenhouse FRS, respectively. However, as the "no action" or future without project alternative also provides this same benefit stream, the project does not have a positive incremental benefit. The benefits of the project are tied to reducing the risk of catastrophic failure of the existing structures and thus reducing the risk to life and property, as described in the plan.

Table 6 - 1-A Summary and Comparison of Candidate Plans – NED Account (Rittenhouse FRS)

	Alternative 1 No Action	Alternative 2 Preferred/NED Rehabilitation/ Decommissioning
Project Investment	$42,800	$9,316,100
Beneficial Annual[1/]	$0	$0
Adverse Annual (Project costs and maintenance)	$42,800	$352,900
Net Beneficial	($42,800)	($352,900)

[1/] The proposed project will provide an estimated $182,400 and $4,021,700 in average annual equivalent damage reduction benefits at Vineyard FRS and Rittenhouse FRS, respectively. However, as the "no action" or future without project alternative also provides this same benefit stream, the project does not have a positive incremental benefit. The benefits of the project are tied to reducing the risk of catastrophic failure of the existing structures and thus reducing the risk to life and property, as described in the plan.

Benefits for the project were based upon the reduction of flood damages. Flood damages under both a With Dams and Without Dams scenario were estimated. The difference in flood damages between the two scenarios can be considered a benefit of retaining flood protection. Because both of the alternatives, including the No Federal Action/Future Without Project, continue to provide flood protection throughout the project life, the benefits are same for each alternative.

The adverse annual benefits include the investment cost amortized at a discount rate of 3.75% over a period of 103-years plus the annual maintenance costs. The net beneficial amounts are computed as the annual benefits, less the adverse annual costs.

The above economic evaluation is documented in the report titled "Powerline, Vineyard Road and Rittenhouse Flood Retarding Structures Supplemental Watershed Plan/Environmental Assessment Economics Evaluation Technical Memorandum" (Gannett Fleming Inc. January, 2013). The economics evaluation memorandum is summarized in the "Investigations and Analysis Report" in **Appendix D**.

Under Alternative 1 (No Action Plan) the existing Vineyard Road FRS and Rittenhouse FRS would remain in place and would continue to provide flood protection up to the 100-year event until the end of the structures design lives (year 2018 and year 2019, respectively). Flows in excess of the 100-year event would be conveyed by the auxiliary spillway and would impact the CAP canal and downstream residential areas west of the dams. The Sponsors have stated that a constructed breach of the dam is not an acceptable alternative.

Alternatives 2 would provide flood protection for the 100-year event or greater. Consistent with P&G, the alternative that has the highest positive net benefits would be identified as the NED Plan (Alternative 3). However, per Section 502.2 of the NRCS National Watershed Program Manual, "In cases where human life is at risk in the event of catastrophic failure of an existing dam that does not meet current safety and performance standards, an overriding reason for an exception to the NED plan requirement exists. To avoid seeking individual exceptions in such cases, the NED plan is defined as the federally assisted alternative with the greatest net economic benefits."

The effects of the alternative plans in terms of the EQ and OSE accounts are summarized in **Table 6 - 2** and Table 6 - 3 respectively.

Table 6 - 2 Summary and Comparison of Candidate Plans – EQ Account

	Alternative 1 **No Federal Action**	**Alternative 2** **Preferred/NED Rehabilitation/Decommissioning**
SOILS		
Geology	Potential inundation and erosion due to dam failure.	Temporary disturbance by excavation and grading activities
Prime and Unique Farmland	Agricultural lands located downstream of dams. Potential inundation and erosion due to dam failure.	Additional flood protection due to rehabilitated Vineyard and Rittenhouse levee.
WATER		
Surface Water Quantity	Potential inundation and erosion due to dam failure.	Rittenhouse levee discharge to Vineyard Road FRS

Table 6 – 2 Summary and Comparison of Candidate Plans – EQ Account (continued)

	Alternative 1 **No Federal Action**	**Alternative 2** **Preferred/NED** **Rehabilitation/Decommissioning**
WATER		
Floodplain Management	Potential exposure the downstream floodplain to flooding risks from overtopping flood events or discharges through the auxiliary spillways above the 100-year event.	Rittenhouse Levee flows directed to the Vineyard Road FRS and thus provide continued flood protection up to the 100-year event for downstream floodplain
PLANTS		
Threatened and Endangered Species	No effect	No effect
Vegetative Communities	No effect	Removal of existing vegetation within project footprint. Effect minimized due to post-construction hydroseeding and other mitigation measures.
ANIMALS		
Fish and Wildlife Habitat	No effect	Short-term minor adverse effect during construction
Threatened and Endangered Species	No effect	No effect
Migratory Birds/Bald and Golden Eagles	No effect	Mitigation for burrowing owl
HUMANS		
Aesthetics	No effect	Moderate effects during construction, no long-term effect; provides opportunity for multi-use
Flood Damages	Downstream properties, residences, business at risk from inundation from dam failure or dam overtopping	Rittenhouse levee discharge to Vineyard Road FRS. Reduced risk of downstream flood damages.
Cost, Sponsor	Continued O&M costs	Action will require significant expenditure of funds.

Table 6 – 2 Summary and Comparison of Candidate Plans – EQ Account (continued)

	Alternative 1 No Federal Action	Alternative 2 Preferred/NED Rehabilitation/Decommissioning
Cost, NED	No effect	Action will require significant expenditure of funds.
Historic Properties/Cultural Resources	No effect	Sites in the APE that will not be subject to project-related impacts will be avoided by project implementation activities. Data recovery studies will be performed to mitigate impacts to all sites likely to suffer project-related impacts.

Table 6 - 3 Summary and Comparison of Candidate Plans – OSE Account

	Alternative 1 No Action	Alternative 2 Preferred/NED Rehabilitation/Decommissioning
Sediment Damage	Potential inundation and erosion due to dam failure. Sediment carried downstream	Rittenhouse levee discharge/sediment to Vineyard Road FRS.
Public Health and Safety	Continued risk of loss-of-life for failure due to dam failure from embankment cracking and/or overtopping	Dam rehabilitation would result in greatest safety improvement-downstream properties, residents, communities would have highest level of flood protection
Land Rights and Relocations	No effect	No effect
Land Use	Breach or failure of dam could limit downstream development	Flood protection provided for the 100-year event
Environmental Justice	Potential to inundate residential structures from dambreak	Flood protection provided for residential structures for next 100 years
Municipal and Irrigation Water	CAP canal subject to inundation in a dam break flood	Flood protection provided for public infrastructure for next 100 years

Table 6 – 3 Summary and Comparison of Candidate Plans – OSE Account

	Alternative 1 No Action	Alternative 2 Preferred/NED Rehabilitation/Decommissioning
Transportation	Continued risk of transportation infrastructure for failure due to dam failure from embankment cracking or overtopping	Flood protection provided for public infrastructure for next 100 years

The effects of the Sponsor's Preferred Alternative/NED (Alternative 2) on resources of national recognition are summarized in **Table 6** - 4.

Table 6 - 4 Effects of the Preferred Alternative on Resources of National Recognition

Types of Resources	Principal Sources of National Recognition	Measurement of Effects	
		Alternative 1 No Action	Alternative 2 Preferred/NED Alternative Rehabilitation/ Decommissioning
Air Quality	Clean Air Act, as amended (42 USC 7401 et seq.)	No effect	Short-term minor adverse effect during construction.
Coastal Zone	Coastal Zone Management Act of 1972, as amended (16 USC 1451 et seq.)	No effect	No effect
Endangered & Threatened Species Critical Habitat	Endangered Species Act of 1973, as amended (16 USC 1531 et seq.)	No effect	No effect
Fish and Wildlife Habitat	Fish and Wildlife Coordination Act (16 USC 661 et seq.)	No effect	Short-term minor adverse effect during construction.
Floodplains	Executive Order 11988, Flood plain Management	No effect	Flood protection provided for the 100-year event for downstream areas

Table 6 – 4 Effects of the Preferred Alternative on Resources of National Recognition

Types of Resources	Principal Sources of National Recognition	Measurement of Effects	
		Alternative 1 No Action	Alternative 2 Preferred/NED Alternative Rehabilitation/ Decommissioning
Historic and Cultural Properties	National Historic Preservation Act of 1966, as amended (16 USC 470 et seq)	No effect	Sites in the APE that will not be subject to project-related impacts will be avoided by project implementation activities. Data recovery studies will be performed to mitigate impacts to all sites likely to suffer project-related impacts.
Prime and Unique Farmland	CEQ Memorandum of August 1, 1980: Analysis of Impacts on Prime or Unique Agricultural Lands in Implementing the National Environmental Policy Act, Farmland Protection Policy Act of 1981.	No effect	Dam rehabilitation (Vineyard) mitigates dam overtopping for IDF
Water Quality	Clean Water Act of 1977, as amended (33 USC 1251 et seq.)	No effect	No effect
Wetlands	Executive Order 11990, Protection of Wetlands; Clean Water Act, Food Security Act of 1985	No effect	No effect
Wild and Scenic Rivers	Wild and Scenic Rivers Act, as amended (16 USC 1271 et seq.)	No effect	No effect

7.0 CONSULTATION AND PUBLIC PARTICIPATION

As noted in **Section 3.0 –** Scope of the Supplemental Watershed Plan and Environmental Assessment, an initial public scoping meeting to solicit input on the planning process for the Powerline, Vineyard Road, and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project FRS was held on November 4, 2010 in Mesa, Arizona (Williams Gateway Airport). Meeting notices/announcements were published in local newspapers, mailed to approximately 11 Federal and State agencies and newsletters sent to approximately several thousand local residents (including disadvantaged and minority publics) and stakeholders, and electronic copies sent to Pinal County. The Sponsor provided a program overview at the meeting. Kimley-Horn and Associates, Inc. provided an overview of the study and the scheduled activities. Several local residents attended the scoping meeting. Since no public comments were received at the scoping meeting no relevant concerns were identified during this public scoping process.

On February 1, 2011, the District and Kimley-Horn conducted a second public presentation in Mesa, Arizona (Williams Gateway Airport). The purpose of the presentation was to present the draft alternatives for the rehabilitation or replacement project. The objective of the presentation was to gain public input and comments on the draft alternatives. Several comments were received from the public in attendance providing input on the draft alternatives.

A third public meeting will be held during the review of this draft Plan/EA for the Preferred Alternative. The meeting will be held in Mesa, Arizona (Williams Gateway Airport). The purpose of the public meeting is to present the Preferred Alternative and summarize the alternatives studied for the PVR project. Comments will be solicited from the public (including disadvantaged and minority publics) on the Preferred Alternative.

Stakeholder meetings and workshops have been conducted with invited public agencies, conservation groups, and land planning group to obtain comments, feedback, and evaluations of tentative alternatives for the PVR dams. A series of seven (7) meetings and workshops were conducted between the period from August 2010 to April 2012. Presentation materials consisting of descriptions and exhibits of proposed alternatives, cost estimates, environmental considerations, land footprints, and multi-use opportunities were discussed and used in the workshops to evaluate, screen, and rank the alternatives. The alternatives were ranked by the stakeholders using a weighted matrix scoring system.

In compliance with Section 106 of the National Historic Preservation Act, NRCS conducted consultations with the Arizona State Historic Preservation Office (SHPO) and with all tribes whose ancestral claims areas overlap the project area. Tribes include the Gila River Indian Community, the Hopi Tribe, the Pascua Yaqui Tribe, the Salt River Pima-Maricopa Indian Community, the San Carlos Apache Nation, the White Mountain Apache Tribe, and the Yavapai-Apache Nation. In November 2012, NRCS and project sponsor representatives met with a representative of the SHPO to initiate the Section 106 process. In January 2013, correspondence was sent to the SHPO and affected tribes describing the purpose and need of the project, the preferred alternative, the area of potential effects for the project, known archaeological sites within the project area, and the need for mitigation of sites that will be adversely affected by project implementation. NRCS invited the SHPO and affected tribes to collaborate in the Section 106 process for the project. Specifically, the SHPO and tribes were requested to identify any previously unrecorded cultural resources, provide any concerns relative to historic properties that may be affected by the project, and provide any information that will assist NRCS with project planning and appropriate treatment of cultural resources.

The Sponsor and Kimley-Horn have conducted several consultations with the U.S. Army Corps of Engineers, Regulatory Branch – Phoenix office in regards to jurisdictional determinations of Waters of the U.S. in the project area. Kimley-Horn prepared on behalf of the Sponsor application of Approved Jurisdictional Determination (AJD) and a Significant Nexus Analysis (SNA). These documents have been submitted to the Corps of Engineers. The Corps has received and reviewed the AJD and the SNA, and per requirements, has forwarded the AJD and SNA to the U.S Environmental Protection Agency (EPA). The EPA is currently reviewing the submittals.

In addition to the public, the following agencies and groups were invited to participate during the planning process:

7.1 Federal Government

- U.S. Army Corps of Engineers
- U.S. Fish and Wildlife Service
- U.S. Environmental Protection Agency
- U.S. Department of the Interior, Bureau of Reclamation
- U.S. Department of the Interior, Bureau of Indian Affairs
- U.S. Department of Homeland Security, Federal Emergency Management Agency
- Bureau of Land Management
- Natural Resources Conservation Service

7.2 State and Local Government

- Office of the Governor
- Arizona State Parks Board, State Historic Preservation Office
- Arizona Department of Agriculture
- Arizona Department of Water Resources
- Arizona Department of Transportation
- Arizona Division of Emergency Management
- Arizona Department of Environmental Quality
- Arizona Game and Fish Department
- Arizona State Land Department
- Maricopa County
- Pinal County
- City of Apache Junction
- City of Mesa
- Town of Queen Creek
- Town of Gilbert

7.3 Tribal Contacts

- Gila River Indian Community
- Hopi Tribe

- Pascua Yaqui Tribe
- Salt River Pima-Maricopa Indian Community
- San Carlos Apache Nation
- White Mountain Apache Tribe
- Yavapai-Apache Nation

8.0 THE PREFERRED ALTERNATIVE

8.1 RATIONALE FOR ALTERNATIVE PREFERENCE

The Preferred Alternative is Alternative 2 – Rehabilitation of Vineyard Road FRS and converting the Rittenhouse FRS to a levee. The rehabilitation alternative meets the project purpose of flood prevention and the formulation goals of the Sponsor to address identified dam safety deficiencies of Vineyard Road FRS and Rittenhouse FRS and to maintain flood protection for the downstream benefitted areas. This alternative also addresses concerns identified through the scoping and planning process. A plan schematic/exhibit for the Preferred Alternative is provided in **Appendix C** as **Figure C-9**.

The dam rehabilitation alternative and converting Rittenhouse to a levee is complete and effective in that it addresses all the identified problems and potential failure modes while addressing all concerns. Additionally it is acceptable to the Sponsor and other stakeholders who will ensure its successful implementation.

The Preferred Alternative calls for raising the dam crest and auxiliary spillways for Vineyard Road FRS in order to safely pass the stability design hydrographs and freeboard hydrographs without overtopping and to provide for adequate flood storage. The rehabilitated Vineyard Road FRS and the Rittenhouse levee will be designed for a 100-year project life.

The NRCS has identified in their memorandum with the subject of "*NED Alternative and Preferred Alternative for the PVR FRS Rehabilitation Project*" (NRCS, Jan. 2013) that the NED alternative (least-cost technically-feasible) is identified as consisting of the following major components and filter options for the Powerline FRS, Vineyard Road FRS and Rittenhouse FRS:

- Replace Powerline FRS with 100-year channels with hardened segments;
- Raise and rehabilitate Vineyard Road FRS with the 'hybrid" filter option;
- Convert Rittenhouse FRS to a levee.

The approximate total project cost for this alternative/filter options is $83M as noted in the Level III report and is reported as the least cost alternative. This alternative describes Alternative 2 and is the NED Plan for the Vineyard Road and Rittenhouse FRSs.

Consistent with P&G, the alternative that has the highest positive net benefits would be identified as the NED Plan. However, per Section 502.2 of the NRCS National Watershed Program Manual, "In cases where human life is at risk in the event of catastrophic failure of an existing dam that does not meet current safety and performance standards, an overriding reason for an exception to the NED plan requirement exists. To avoid seeking individual exceptions in such cases, the NED plan is defined as the federally assisted alternative with the greatest net economic benefits".

Section 5.2 presented a discussion of Alternatives 8B and 8A in relation to the Preferred Alternative and the NED Plan. As noted Alternatives 8A and 8B were carried forward into a Level III analysis (*Level III Final Alternatives Summary Report* – Kimley-Horn, September 2012). The Level III analysis conducted further evaluations of Alternatives 8A and 8B. The alternatives differ in the treatment of Rittenhouse FRS and in the filter treatments for Vineyard Road FRS and Rittenhouse FRS in Alternative 8B. The Level III report identified the Sponsor's Preferred

Alternative as the option with the upstream sloping filters for dam rehabilitations for both Vineyard Road FRS and Rittenhouse FRS. The Level III report identified the Preferred Alternative as Alternative 8A with the option of a 'hybrid' filter for the dam rehabilitation of Vineyard Road FRS, converting the Rittenhouse FRS to a levee, and replacing Powerline FRS with a 100-year channel.

The Preferred Alternative and the NED Plan for the Vineyard Road FRS and the Rittenhouse levee is one in the same for this Plan/EA. The Preferred Alternative and NED Plan for the Powerline FRS (which is replacing the FRS with a channel) are provided in the "*Draft Supplemental Watershed Plan and Environmental Assessment for the Powerline FRS*" (Kimley-Horn January 2013).

8.2 Measures to Be Installed

The features of the Preferred Alternative are summarized below which are based on the results of the technical investigations and analyses, and in accordance with the Sponsor and NRCS requirements.

8.2.1 Embankments

Upstream embankment modifications to the Vineyard Road FRS includes installation of an 'hybrid' filter constructed to a depth of below existing cut-off trench to competent material and raising the dam crest elevation (Vineyard Road FRS from 1580.3 feet to 1592.0 feet). Borrow material for the dam raise may be derived from borrow areas within the reservoir pool. The north abutment of Vineyard Road FRS will be extended to accommodate the design of the auxiliary spillway, raised dam crest elevation, and the confluence with the Powerline Channel. A typical section of the Vineyard Road FRS including the hybrid filter is provided in **Appendix** C as **Figure C-10**.

The Rittenhouse FRS north abutment will be removed to allow Rittenhouse flows to be conveyed to the Vineyard Road FRS flood pool. The Rittenhouse FRS crest will be lowered to an elevation of the 100-year water surface plus 3-feet of freeboard. The excess spoil material from the embankment excavation is anticipated to be stockpiled within the Sponsor's easement at locations to be determined with the land owner – Arizona State Land Department. A typical section of the Rittenhouse levee is provided in **Appendix** C as **Figure C-15**.

8.2.2 Principal Spillways

The Preferred Alternative includes removal of the existing principal spillways at Vineyard Road FRS and at Rittenhouse FRS. The Vineyard Road spillway will be replaced with new T-top baffled riser principal spillways based on NRCS standards and outlet works consisting of an impact basin (energy dissipator). No principal spillway is required at the Rittenhouse levee. A plan view of the principal spillway is provided in **Appendix** C as **Figure C-11**.

The design of the principal spillway is based on the NRCS requirement to drain the runoff from the 100-year 10-day storm event (Principal Spillway Hydrograph, PSH) to 15% of the inflow volume within 10 days or less without passing flow over the auxiliary spillways. The invert elevation at the intake of the principal spillways has been located above the anticipated 100-year sediment storage levels.

8.2.3 *Auxiliary Spillways*

The Preferred Alternative will raise the auxiliary spillway crest elevations for both the north and south auxiliary spillways for Vineyard Road FRS. The north and south auxiliary spillways for Vineyard Road FRS will be raised from 1576.1 (north) and 1575.5 (south) feet to 1580.6 feet. New concrete drop structures will be constructed for the Vineyard Road FRS auxiliary spillways and will be similar to the auxiliary spillway provided at White Tanks FRS No. 3. This structure includes a concrete control spillway weir, downstream concrete apron, and impact blocks for energy dissipation. Rip-rap erosion control blankets are provided at the approach section to the spillway weir and downstream of the impact blocks to control downstream scour. A typical section of the auxiliary spillway is provided in **Appendix C** as **Figure C-12**.

The depths of the auxiliary spillways were designed to safely pass the stability design hydrograph and the freeboard hydrographs through the existing widths of the spillways. The spillways locations will remain the same location as existing. The NRCS SITES model was used to evaluate the breach potential of the existing spillways allowing for the design of the appropriate planning design depth of the drop structures.

8.3 Mitigation Features

Clearing and grading activities due to construction for the raised dams and modifications of the auxiliary spillways and construction of O&M roads will temporarily disturb existing vegetation. Disturbed areas due to construction activities will be hydro-seeded with native plant mix. The mitigation may include planting new tallpot mesquite trees (approximately 100 acres) and salvage of some mature mesquite trees and transplanting in designated areas adjacent to the embankments.

Weed prevention methods will be implemented during construction activities. These methods wil be determined in final design but may include: use of certified weed free seed, sterilized straw mulch with a tackifier so the straw mulch holds onto the ground, washing vehicles off before they enter the site, and managing adjacent weed populations to the extent possible (to prevent seed drift). Also, the use of pre-emergent herbicide could be considered for any non-planted areas that will be plated with Decomposed Granite or Rip Rap. A further measure would be to not allow weeds to colonize any soil stockpile areas before the re-use of the stored soil on site.

Erosion control measures, both temporary during construction and permanent measures will be installed. Erosion control will be specified in the NRCS contract specifications. Section 7.4 below states the Sponsors are responsible for a 402 National Pollutant Discharge Elimination System Permit (NPDES) for Stormwater from Construction Sites which includes the preparation of a Stormwater Pollution Prevention Plan (SWPPP).

The installation activities will be required to conform with local and county dust control regulations and measures. Dust control will be specified in the NRCS contract specifications.

8.4 Permits and Compliance

The Sponsors are responsible for all permits, including a 402 National Pollutant Discharge Elimination System Permit (NPDES) for Stormwater from Construction Sites, and the water quality certification (401 certification) both from the Arizona Department of Environmental Quality, and submittal Form SCS-ADS- 78 (Real Property Assurances).

The final determination of the applicability of NPDES permitting requirements will be made upon completing the design of the proposed project; if applicable, the final construction contract will include NPDES planning and implementation as a responsibility of the construction contractor. Completion of the Final Watershed Plan-EA and a Finding of No Significant Impact will complete all requirements of NEPA.

If during the installation cultural resources are discovered, all work activities associated with the installation activity will stop and procedures detailing cultural resources discovered during implementation will be implemented per NRCS contract specifications. All work will comply with Arizona State Level Agreement, NRCS General Manual 420 Part 401, and the National Cultural Resources Procedures Handbook [H 190 Part 601].

An encroachment permit may be required from the CAP for construction within the CAP canal right-of-way.

8.5 Costs

The estimated installation costs for the Preferred Alternative/NED are $52,928,300. This estimated installation includes the cost of construction plus NRCS engineering and project administration costs, as well as the Sponsor's engineering and project administration costs.

NRCS **Tables 1 through 6** are included in this section of this Plan-EA and presents information about the Preferred Alternative. The costs shown in **Tables 1** and **2** for the planned rehabilitation work were estimated using a 2012 price level. Annual costs were based on a 2012 discount rate of 3.75% over a project life of 103-years. **Table 3** summarizes important physical characteristics of the rehabilitated dams. **Tables 4**, **5**, and **6** highlight the amortized or annual average dollar costs and benefits for the planned rehabilitation work. An outline of the table contents follows:

- Table 1. Estimated Installation Cost: This table documents the federal and non-federal funding sources respectively. The table shows federal expenditures under the Watershed Protection and Flood Prevention Act (PL 83-566).
- Table 2. Estimated Cost Distribution: This table shows estimated costs to be charged to the PL 83-566 Funds, and those to be borne by the Sponsors.
- Table 3. Structure Data: This table shows important physical characteristics and geometry of the rehabilitated earth embankment for the Vineyard Road FRS.
- Table 3a. Dikes: This table important physical characteristics and geometry of the Rittenhouse Levee.
- Table 4. Estimated Average Annual Cost: This table shows the anticipated installation costs of the Preferred Alternative discounted over the evaluation period of 103 years.
- Table 5. Estimated Average Annual Damage Reduction Benefits: This table summarizes flood damage reduction provided by the proposed project. It includes a summary of the agricultural and non-agricultural benefits that the proposed project would provide.
- Table 6. Comparison of Benefits and Costs: This table summarizes the benefits and costs of the Preferred Alternative and documents the overall benefit-to-cost ratio of the proposed project.

8.6 INSTALLATION AND FINANCING

8.6.1 FRAMEWORK

All works of improvement will be installed in accordance with applicable state and federal regulations. Installation of the work will be accomplished through a Project Agreement, which defines and details the roles and responsibilities of the NRCS and the Sponsors.

8.6.2 PLANNED SEQUENCE OF INSTALLATION

The major construction elements in the Preferred Alternative can be divided into the Vineyard Road FRS rehabilitation and the Rittenhouse FRS conversion to a levee.

The work for the rehabilitated Vineyard Road FRS should be completed first. The work for the Powerline Channel (under the *Powerline FRS Supplemental Watershed Plan/EA*) may be completed after the rehabilitation of the Vineyard Road FRS. The work for the rehabilitated Rittenhouse FRS may be initiated after substantial completion of the Powerline Channel. Erosion protection measures may be placed when grading is completed for the specific elements.

8.6.3 RESPONSIBILITIES

The responsibilities of the Sponsors and the NRCS, set forth in the original work plan, will continue in accordance with this Supplemental Watershed Plan-EA and with the Supplemental Watershed Agreement.

The NRCS will provide technical assistance to the Sponsors with the design and construction of the rehabilitation/decommissioning project. NRCS will:

- Provide contract administration technical assistance
- Provide construction management technical assistance
- Provide financial assistance equal to 65% of project costs, not to exceed 100% of actual construction costs
- Execute a cooperative agreement with the Sponsors before either party initiates work involving funds of the other party. Such agreements will set forth in detail the financial and working arrangements and other conditions that are applicable to the specific works of improvement.

The Sponsors will:

- Secure all needed permits, easements (if required), and rights for installation, operation, and maintenance of the new channels.
- Utilities need to be researched as part of the design phase of the project. Relocation of utilities is the responsibility of the utility owner.
- The Sponsors will provide leadership in updating their existing Emergency Action Plan (EAP) prior to construction and will update the EAP annually with local emergency response officials. The purpose of the EAP is to outline appropriate actions and to designate parties responsible for those actions in the event of a potential failure of the channels.

- Execute an updated Operation and Maintenance agreement with NRCS for the Vineyard Road FRS and Rittenhouse Levee.
- Execute a cooperative agreement with NRCS before either party initiates work involving funds of the other party. Such agreements will set forth in detail the financial and working arrangements and other conditions that are applicable to the specific works of improvement.
- Provide nonfederal funds for cost-sharing of the project at a rate equal to, or greater than, 35% of project costs.
- Provide local administrative and construction management services necessary for installation of the project.
- Comply with all applicable Federal, State, and local floodplain management laws, ordinances and regulations.
- Be responsible for enforcing all associated project easements and rights-of-way.

The Flood Control District of Maricopa County will provide technical leadership for the installation, operation, and maintenance of the structural measures installed under the Supplemental Watershed Plan and Environmental Assessment. The NRCS will work closely with the Sponsor in the development of an operation and maintenance plan and will participate in annual inspections jointly with the Sponsor and the State Office of Dam Safety.

Contracts to implement the Preferred Alternative measures will be between the District and the selected construction firm. The NRCS will facilitate the request for funding from appropriations for the dam rehabilitation program. The NRCS will provide the financial assistance to the District by means of a cooperative agreement.

All works of improvement will be installed in accordance with NRCS standards and specifications and meet all applicable local, State, and Federal regulations.

8.6.4 Real Property and Relocations

Implementation of the Preferred Alternative will not require procurement of real property rights by the Sponsors.

- Additional temporary work easements for over excavation, loading, and unloading may be required in the vicinity of the CAP canal for removal of the existing dam embankment. Areas for construction staging and stockpiling can be located within the existing flood pool area, and will not require additional temporary easement.
- It appears that no relocations as defined by the Uniform Relocation Act will be needed. However, if any relocations are identified during installation of this undertaking, they must conform with the Uniform Relocation Act and NRCS procedures, which are outlined in NRCS Property Management Regulations.

8.6.5 Other Agencies

- The Preferred Alternative will require review and concurrence from the ADWR Dam Safety Division.

- Hauling on local roadways will likely require a haul-road permit that will be the responsibility of the construction contractor.

8.6.6 *Financing*

The Sponsors are responsible for 35% of the total decommissioning cost. The NRCS will provide 65% of the total decommissioning cost with funding from PL 83-566.

8.6.7 *Operation, Maintenance, and Replacement*

The Flood Control District of Maricopa County will continue to operate and maintain the Vineyard Road FRS and Rittenhouse levee. The operation, maintenance, and replacement program is carried out as prescribed in the Operation and Maintenance Agreement. A new O&M agreement between the Sponsors and NRCS will be written and executed prior to the beginning of construction. The agreement is developed in accordance with the NRCS National Operation and Maintenance Manual, and provides for inspections, reports, and procedures for performing maintenance items and will be in force during the 100-year evaluated project life. Operation includes the administration, management, and performance of non-maintenance actions needed to keep completed measures safe and functioning as planned.

The National Operation and Maintenance Manual will be used as a guide for operation.

Maintenance includes performing work and providing materials to prevent the deterioration of the installed works. Maintenance also includes repairing damage and replacing the measure or its components. Damage to completed measures caused by normal deterioration, drought, flooding from rainfall greater-than-design rainfall, or vandalism is considered maintenance. Maintenance includes both routine and recurring needs such as:

- Annual control of woody species on or near the levee.
- Rodent control on the main embankment.
- Vector control, if necessary.
- Repair and maintenance of the existing drainage structures.
- Other specific items will be identified during design.

Inspections are necessary to ensure that the installed measures are safe and functioning properly. Inspections are to: a) assess the adequacy of OM&R activities; b) identify needed OM&R work; c) identify unsafe conditions, including significant changes in the use of the floodplain below the channel; d) specify ways of relieving unsafe work or performing other needed work; and e) set action dates for performing corrective actions.

The Sponsors are responsible for inspecting completed measures. Inspections will be made at least annually on a regularly scheduled basis for the life of the structure and after any major events such as floods or earthquakes. The Operation and Maintenance Agreement will specify any other needed inspections. The NRCS may, depending on the availability of staff, assist the Sponsors with the inspections. Inspection reports will be supplied to NRCS following each inspection.

The estimated annual cost of operation and maintenance for the Preferred Alternative is $291,700.

8.7 NRCS National Watershed Manual Tables

NRCS Table 1 – Estimated Installation Cost

Vineyard Road FRS and Rittenhouse FRS
Williams-Chandler Watershed, Maricopa and Pinal Counties, AZ

(Dollars) [1/ 2/]

Installation Cost Item	Unit Number	Estimated Cost[1/, 2/]		
		Federal Funds	Other Funds	Total
Rehabilitation of Vineyard FRS	No. 1	$28,053,500	$15,558,700	$43,612,200
Rehabilitation of Rittenhouse FRS	No. 1	$6,177,800	$3,138,300	$9,316,100
Total Project		$34,231,300	$18,697,000	$52,928,300

January 2013

[1/] 2012 Prices.
[2/] Federal Funds include NRCS Engineering Services and Project Administration ($1,300,000), which are not included when calculating eligible federal cost share. Permit costs ($964,800) are also not included. Therefore, federal cost share is based on Total Eligible Project Cost of $50,663,500.

NRCS Table 2 – Estimated Cost Distribution - Structural and Non-Structural Measures

Vineyard Road FRS and Rittenhouse FRS
Williams-Chandler Watershed, Maricopa and Pinal Counties, AZ

(Dollars) [1/]

Works of Improvement	Installation Cost ----------Federal Funds[2/]---------				Installation Costs ----------Other Funds-----------						Total Installation Cost
	Construction	Engineering Services	Project Admin.	Total Federal Funds	Construction	Engineering Services	Real Property Rights	Required Permits	Project Admin.	Total Other Funds	
Rehabilitation of Vineyard FRS	$27,403,500	$600,000	$50,000	$28,053,500	$13,541,300	$1,204,400	$0	$803,000	$10,000	$15,558,700	$43,612,200
Rehabilitation of Rittenhouse FRS	$5,527,800	$600,000	$50,000	$6,177,800	$2,723,800	$242,700	$0	$161,800	$10,000	$3,138,300	$9,316,100
Grand Total	$32,931,300	$1,200,000	$100,000	$34,231,300	$16,265,100	$1,447,100	$0	$964,800	$20,000	$18,697,000	$52,928,300

January 2013

[1/] Price Base: 2012.
[2/] Federal Engineering Services and Project Administration costs, as well as permit costs, are not included when calculating eligible federal cost share. Therefore, federal cost share is based on Total Eligible Project Cost of $50,663,500.

NRCS Table 3 – Structural Data

Vineyard Road FRS and Rittenhouse FRS
Williams-Chandler Watershed, Maricopa and Pinal Counties, AZ

Item	Unit	Vineyard Road FRS
Hazard Class of Structure		High (C)
Seismic Zone		Sonoran Zone
Uncontrolled Drainage Area 1/	mi^2	52.7 (146.8 total)
Total Drainage Area 1/	mi^2	52.7 (146.8 total)
Runoff Curve No. (1-day) (AMC II)		83
Time of Concentration (Tc)	hrs	4.12
Elevation Top of Dam 2/	ft	1593.0
Elevation Crest Auxiliary Spillway	ft	1581.4 (North) 1581.4 (South)
Elevation Crest High Stage Inlet	ft	1573.1
Auxiliary Spillway Type		Concrete drop structure with downstream Earthen Channel
Auxiliary Spillway Bottom Width	ft	300 (North) 300 (South)
Auxiliary Spillway Exit Slope	percent	0.0129 (North) 0.0107 (South)
Maximum Height of Dam	ft	29.2
Volume of Fill	yd^3	2,942,000
Total Capacity 3/	acre-ft	10,568
Sediment Submerged	acre-ft	2,893
Floodwater Retarding	acre-ft	7,675
Surface Area 3/		
Sediment Pool	acres	599
Floodwater Retarding Pool	acres	1,259
Principal Spillway Design		
Rainfall Volume (1-day) 4/	in	3.75 (4.07, 3.84)
Rainfall Volume (10-day) 4/	in	7.28 (8.25, 7.21)
Runoff Volume (1-day) 4/	in	0.86 (0.90, 0.83)
Runoff Volume (10-day) 4/	in	1.59 (1.78, 1.44)
Capacity of High Stage (max.) 5/	ft^3/s	524
Dimensions of Conduit 5/	in	66
Type of Conduit 5/		RCP
Frequency Operation-Auxiliary Spillway	percent chance	< 1.0

NRCS Table 3 – Structural Data

Vineyard Road FRS and Rittenhouse FRS
Williams-Chandler Watershed, Maricopa and Pinal Counties, AZ (continued)

Item	Unit	Vineyard Road FRS
Auxiliary Spillway Hydrograph		
Rainfall Volume 6/	in	4.30
Runoff Volume 6/	in	2.77
Storm Duration	hrs	6
Velocity of Flow (Ve)	ft/s	TBD in Final Design
Max. Reservoir Water Surface Elev.	ft	TBD in Final Design
Freeboard Hydrography		
Rainfall Volume 5/	in	9.72 (9.99, 9.81)
Runoff Volume 6/	in	7.70
Storm Duration	hrs	6
Max. Reservoir Water Surface Elev. 7/	ft	1590.8
Capacity Equivalents		
Sediment Volume 7/	in	0.4
Floodwater Retarding Volume 7/	in	1.0

January 2013

1/ First value listed is for the Vineyard Road Watershed only. The second value in parenthesis is for the total Powerline, Vineyard Road and Rittenhouse watershed.
2/ Includes 1 feet of freeboard.
3/ Crest of Auxiliary Spillway.

4/ For Vineyard Road only. Rainfall values for Powerline and Rittenhouse respectively are provided in parenthesis.
5/ For Vineyard Road only, but includes inflows from Powerline and Rittenhouse.
6/ For Vineyard Road
7/ For total watershed of Powerline, Vineyard Road and Rittenhouse.

NRCS Table 3a – Structural Data – Dikes 1/

Vineyard Road FRS and Rittenhouse FRS
Williams-Chandler Watershed, Maricopa and Pinal Counties, AZ

Dike	Stationing	Top Width [ft]	Average Side Slope [H:1V]	Average Height of Dike [ft]	100-year Frequency Velocity [ft/s]	Dike Protection	Volume of Earth Fill 1/ [yd^3]
Rittenhouse Levee	10+00	39	3	0	7.8	Rock Riprap	4954
	25+00	0	3	4	7.8	Rock Riprap	8500
	50+00	35	3	14	7.8	Rock Riprap	28759
	75+00	35	3	14	7.8	Rock Riprap	22028
	100+00	35	3	13	7.8	Rock Riprap	22028
	125+00	35	3	12	7.8	Rock Riprap	22028
	150+00	40	3	13	7.8	Rock Riprap	24111
	175+00	50	3	10	7.8	Rock Riprap	31194
	190+00	80	3	6	7.8	Rock Riprap	30531
	195+00	110	3	0	7.8	Rock Riprap	22044

1/ Dike is Class I (reference NRCS Engineering Standard No. 356)
Prepared: January 2013

NRCS Table 4 – Estimated Average Annual National Economic Development (NED) Costs

Vineyard Road FRS and Rittenhouse FRS
Williams-Chandler Watershed, Maricopa and Pinal Counties, AZ

(Dollars) [1/] [2/]

Works of Improvement	----------Project Outlays-----------		Total
	Amortization of Rehabilitation Cost[2/]	Operation, Maintenance and Replacement Cost	
Vineyard FRS	$1,448,700	$248,900	$1,697,600
Rittenhouse FRS	$310,100	$42,800	$352,900
TOTAL	$1,758,800	$291,700	$2,050,500

January 2013

[1/] Price Base 2012.

[2/] Amortized for 102 years at 3.750 percent.

NRCS Table 5 – Estimated Annual Flood Damage Reduction Benefits
(Avg. Annual Equivalents)
Vineyard Road FRS and Rittenhouse FRS
Williams-Chandler Watershed, Maricopa and Pinal Counties, AZ
(Dollars) [1/]

Item	Future With Project		Future Without Project		Total Damage Reduction Benefits	Benefits of All Alternatives (Average Annual Equivalent Value[2])
	Ag. Related	Non-Ag. Related	Ag. Related	Non-Ag. Related		
Vineyard FRS						
Floodwater						
Residential		$78,300		$78,300	$0	$0
Commercial/Industrial		$29,200		$29,200	$0	$0
Agriculture	$1,400		$1,400		$0	$0
Infrastructure						
Roadways		$5,400		$5,400	$0	$0
Irrigation Canal	$1,700		$1,700		$0	$0
Insurance Administration Costs		$59,500		$59,500	$0	$0
Subtotal Vineyard FRS	**$3,100**	**$172,400**	**$3,100**	**$172,400**	**$0**	**$0**
Rittenhouse Levee						
Floodwater						
Residential		$1,183,800		$1,183,800	$0	$0
Commercial/Industrial		$15,100		$15,100	$0	$0
Institutional		$2,428,700		$2,428,700	$0	$0
Agriculture	$217,500		$217,500		$0	
Infrastructure						
Roadways		$5,000		$5,000	$0	$0
Irrigation Canal	$0		$0		$0	
Insurance Administration Costs		$19,500		$19,500	$0	$0

NRCS Table 5 – Estimated Annual Flood Damage Reduction Benefits

(Avg. Annual Equivalents)
Vineyard Road FRS and Rittenhouse FRS
Williams-Chandler Watershed, Maricopa and Pinal Counties, AZ (continued)
(Dollars) 1/

Item	Future With Project		Future Without Project		Total Damage Reduction Benefits	Benefits of All Alternatives (Average Annual Equivalent Value[2])
	Ag. Related	Non-Ag. Related	Ag. Related	Non-Ag. Related		
Subtotal Rittenhouse FRS	**$217,500**	**$3,652,100**	**$217,500**	**$3,652,100**	**$0**	**$0**
TOTAL	**$220,600**	**$3,824,500**	**$220,600**	**$3,824,500**	**$0**	**$0**

January 2013

[1/] Price Base 2012. Amortized for 103 years at 3.75 percent.

[2/] Calculated as follows: calculate present value of damage reduction in each year, sum the present values, and then calculate the amortized annual amount ("average equivalent value") that would yield the present value sum. Present value and amortization use the discount rate of 3.75%. The benefits of the project are tied to reducing the risk of catastrophic failure of the existing structures and thus reducing the risk to life and property, as described in the plan.

NRCS Table 6 – Comparison of NED Benefits and Costs

Vineyard Road FRS And Rittenhouse FRS
Williams-Chandler Watershed, Maricopa and Pinal Counties, AZ

(Dollars) [1/]

Works of Improvement	Average Annual Benefits (Ag-Related)	Average Annual Benefits (Non Ag-Related)	Average Annual Costs[2/]	Benefit/ Cost Ratio[3/]
Vineyard FRS	$0	$0	$1,697,600	0.0 to 1.0
Rittenhouse FRS	$0	$0	$352,900	0.0 to 1.0

January 2013

[1/] Price Base 2012.

[2/] From Table 4.

3/ The proposed project will provide an estimated $182,400 and $4,021,700 in average annual equivalent damage reduction benefits at Vineyard FRS and Rittenhouse FRS, respectively. However, as the "no action" or future without project alternative also provides this same benefit stream, the project does not have a positive incremental NED benefit. The benefits of the project are tied to reducing the risk of catastrophic failure of the existing structures and thus reducing the risk to life and property, as described in the plan.

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10.0 LIST OF PREPARERS

The following individuals participated in the preparation of the Plan/EA.

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Name	Present Title	Education	Experience (Years)	Registration
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Dino DeSimone	Resource Conservationist	B.S., Evt. Resources	30	
Mike Luecker	State Hydraulic Engineer	B.S., M.S.E. Civil Engineering	13	P.E.
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Seth Fiedler	Economist	B.A., Economics, M.C.P.	18	
Flood Control District of Maricopa County				
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Mike Greenslade	Dam Safety Engineer	B.S. Geological Engineering	34	P.E.
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Table 10 - 1 List of Preparers (continued)

Name	Present Title	Education	Experience (Years)	Registration
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Alex Menez, P.E., CFM	Civil Engineer	B.S., M.S. Civil Engineering	12	P.E., CFM
Melanie Fife, P.E., CFM	Civil Engineer	B.S., M.S. Civil Engineering	6	P.E., CFM
Tony Doucette, P.E., CFM	Civil Engineer	B.S., M.S. Civil Engineering	6	P.E., CFM
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Subconsultants				
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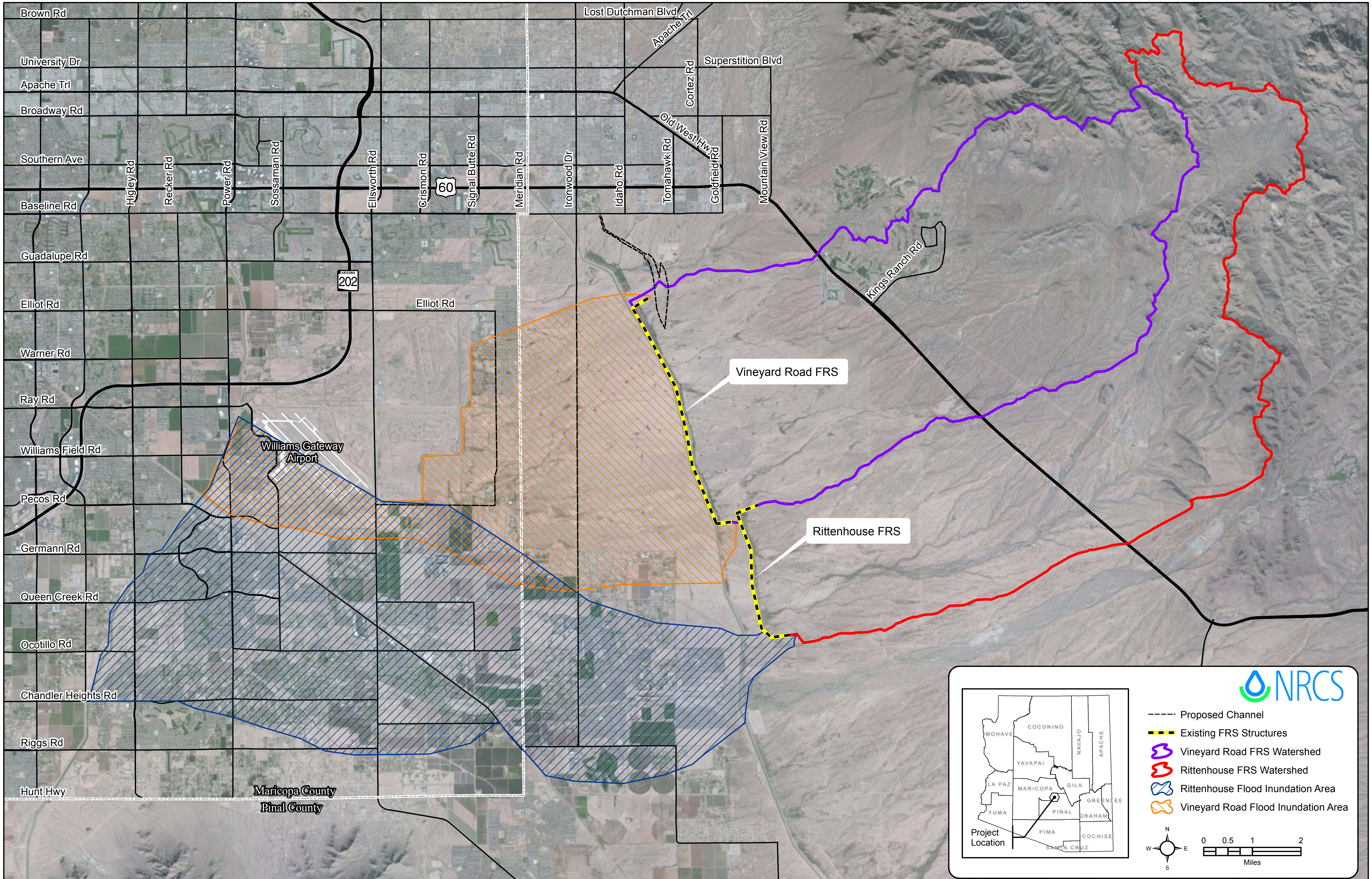
11.0 TOPIC INDEX

<u>TOPIC</u> PAGE NO.

Appendix A Comments and Responses

Appendix B Project Map



NO. | REVISION | BY | DATE | APPR.

Kimley-Horn and Associates, Inc.

2012 KIMLEY-HORN AND ASSOCIATES, INC.

Engineering, Planning and Environmental Consultants

7740 North 16th Street, Suite 300
Phoenix, Arizona 85020 (602) 944-5500

SCALE(H): 1"= 6000'
SCALE(V): N/A
DESIGNED BY: TDD
DRAWN BY: JAG
CHECKED BY: RAE
DATE: SEPT, 2012

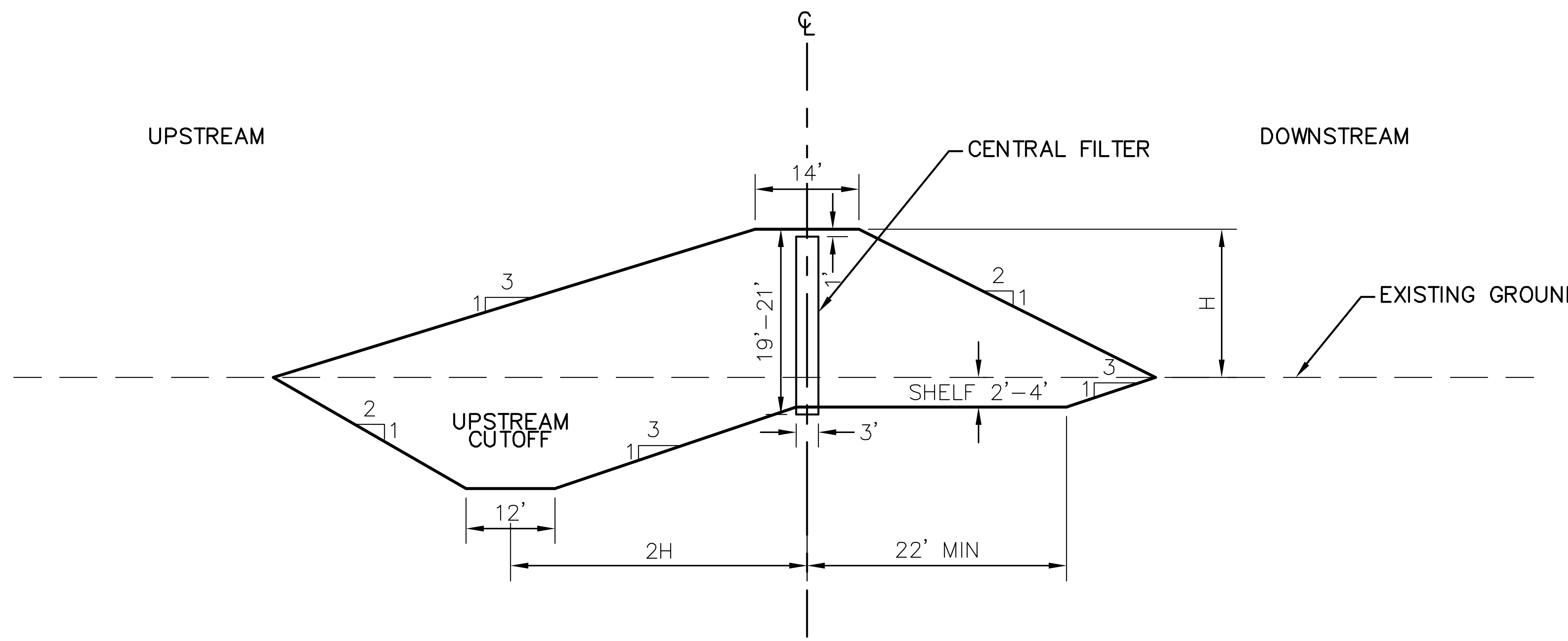
Figure B-1: Vineyard Road and Rittenhouse FRS Project Location Map

PROJECT NO.
91131019

DRAWING NAME
POWERLINE_PROJECT_MAP.MXD

Appendix C Support Maps

VINEYARD ROAD FRS



NOTE: THE CENTRAL FILTER EXTENDS FROM STATIONS 85+00 TO 360+00 AND EXTENDS TO DEPTHS OF 19 TO 21 FEET BELOW THE DAM CREST, CORRESPONDING TO DEPTHS OF BETWEEN 2.5 TO 4.5 FEET BELOW THE ORIGINAL GROUND SURFACE. THERE ARE NO FINGER DRAINS CONNECTING THE CENTRAL FILTER TO THE DOWNSTREAM TOE OF THE EMBANKMENT.

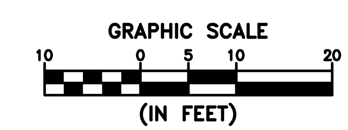


Figure C-1: Vineyard Road FRS Existing Embankment - Typical Section

Kimley-Horn and Associates, Inc.

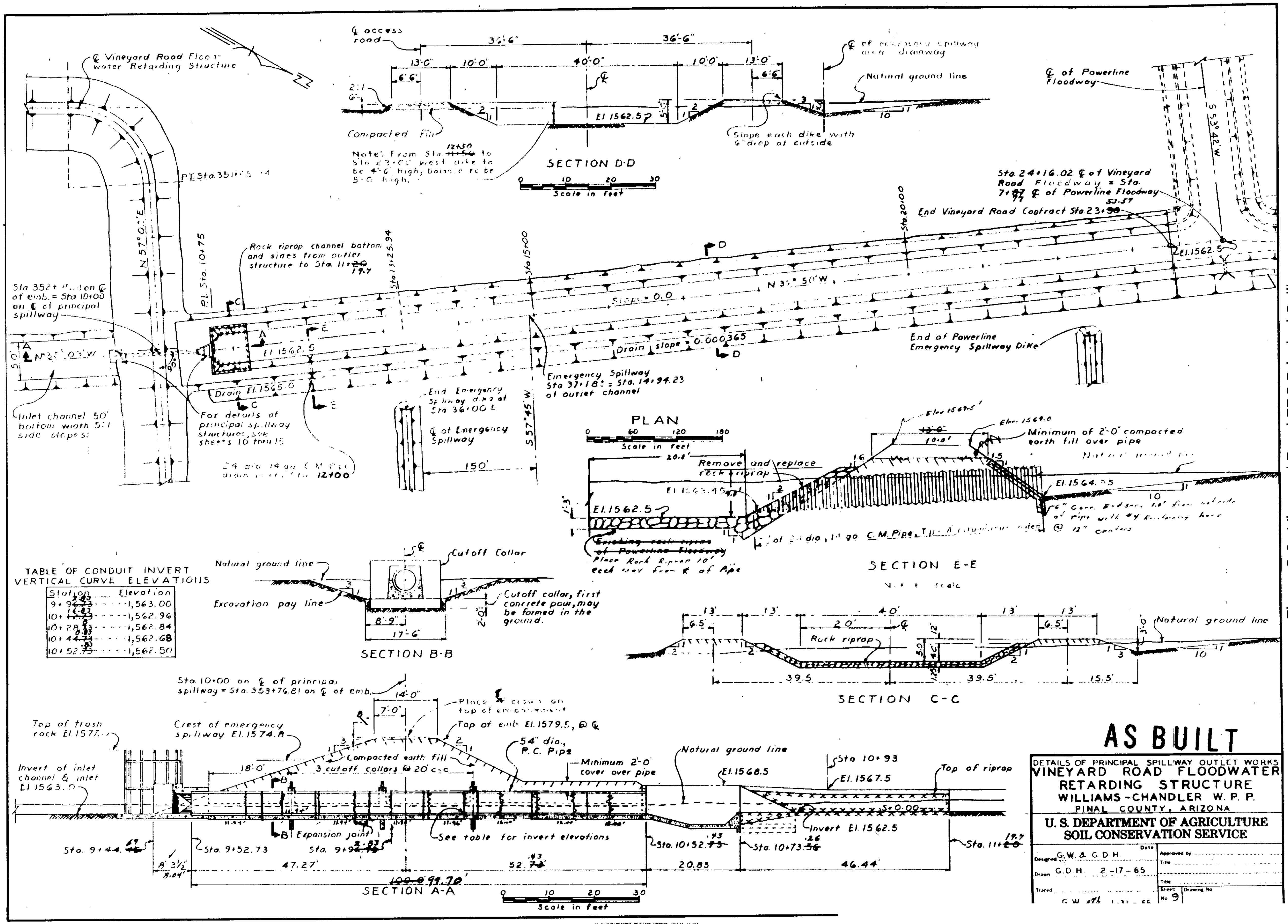


TABLE OF CONDUIT INVERT VERTICAL CURVE ELEVATIONS

Station	Elevation
9+96.73	1,563.00
10+15.73	1,562.96
10+28.73	1,562.84
10+44.73	1,562.68
10+52.73	1,562.50

Figure C-2. Vineyard Road FRS Principal Spillway

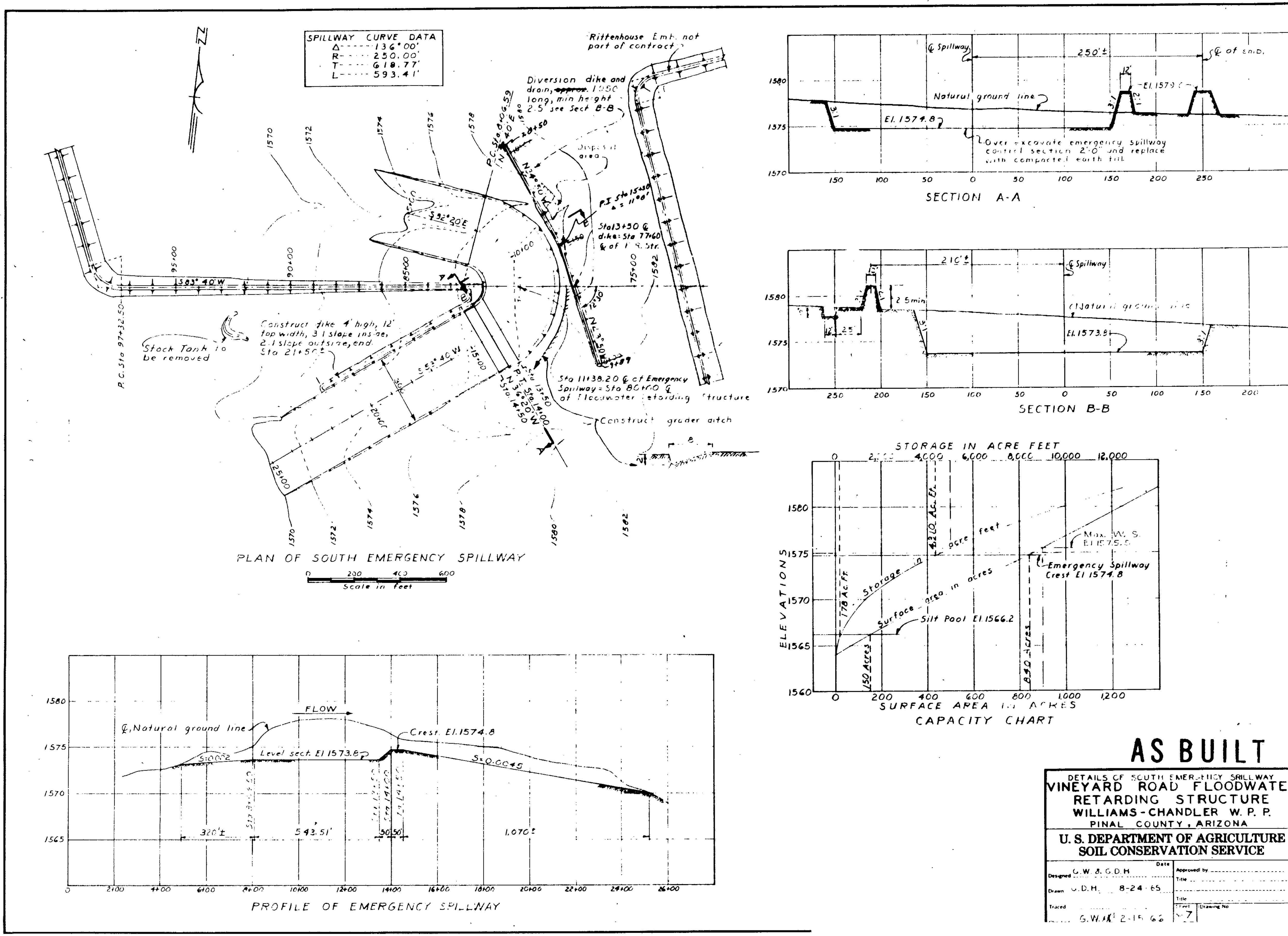


Figure C-3. Vineyard Road FRS South Auxiliary Spillway

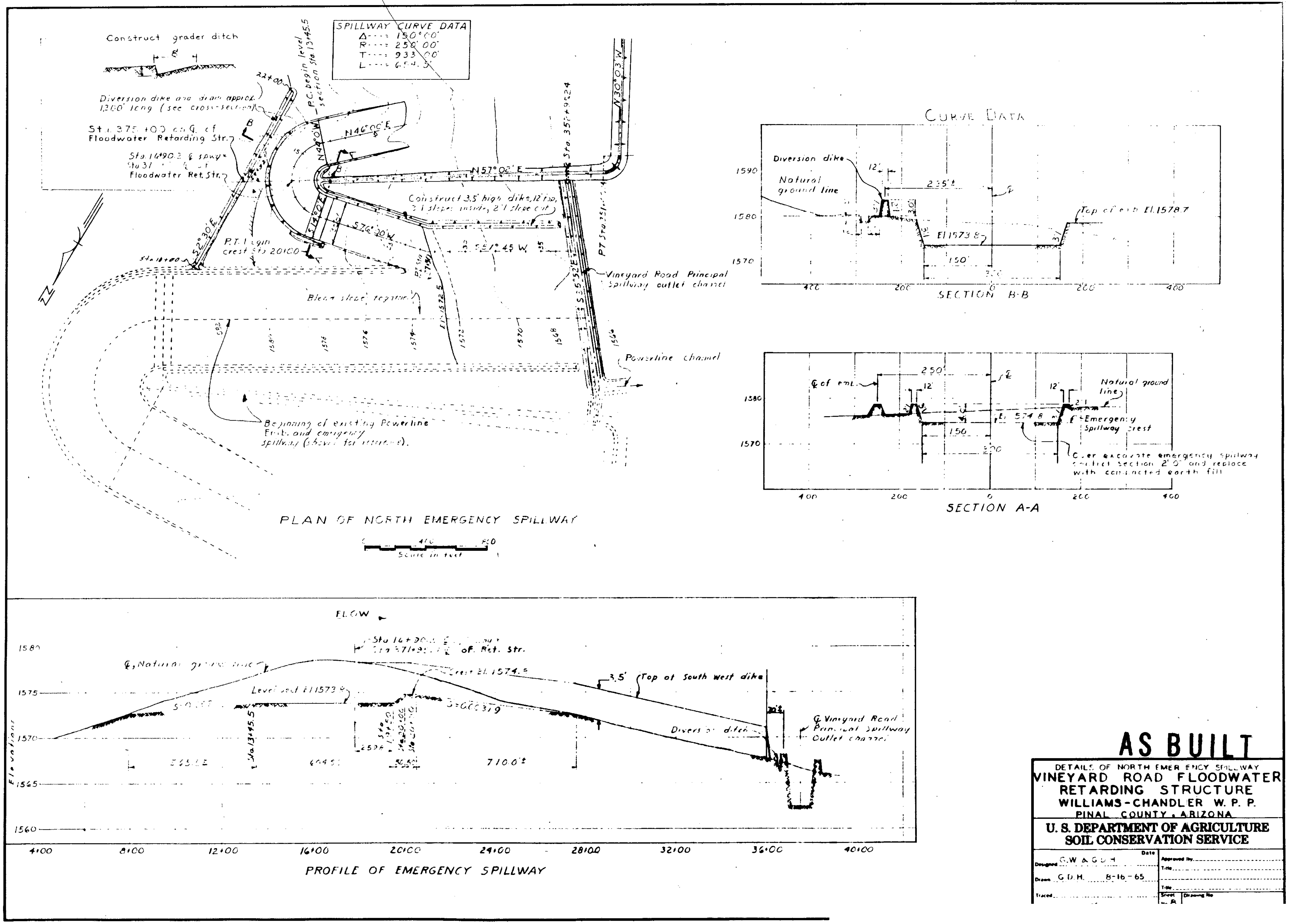
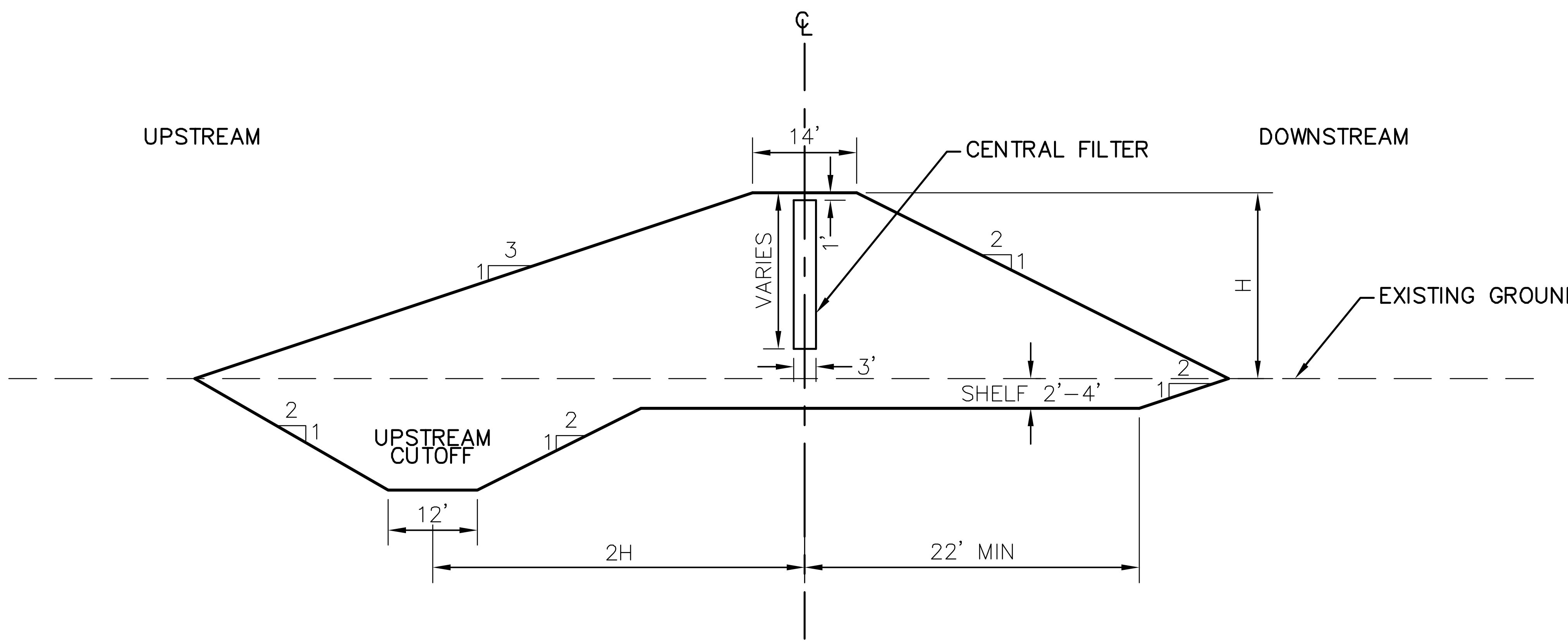


Figure C-4: Vineyard Road FRS North Auxiliary Spillway

RITTENHOUSE FRS



NOTE: THE CENTRAL FILTER EXTENDS FROM STATIONS 80+00 TO 210+00. THE CENTRAL FILTER IS NOT PRESENT IN THE SOUTHERN 5,000 FEET OF THE DAM FROM STATIONS 30+00 TO 80+00. THE FILTER EXTENDS AN AVERAGE OF 12.8 FEET BELOW THE CREST BETWEEN STATIONS 80+00 AND 109+72 AND EXTENDS AN AVERAGE OF 15.8 FEET BELOW THE CREST BETWEEN STATIONS 109+72 AND 200+00. THE FILTER VARIES FROM 14.6 TO 6.9 FEET IN DEPTH BETWEEN STATIONS 200+00 AND 210+00. THE FILTER DOES NOT EXTEND THROUGH THE EMBANKMENT INTO NATIVE SOILS.

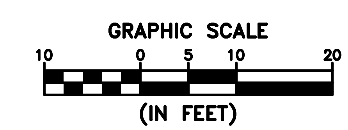


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Figure C-5. Rittenhouse FRS Existing Embankment – Typical Section

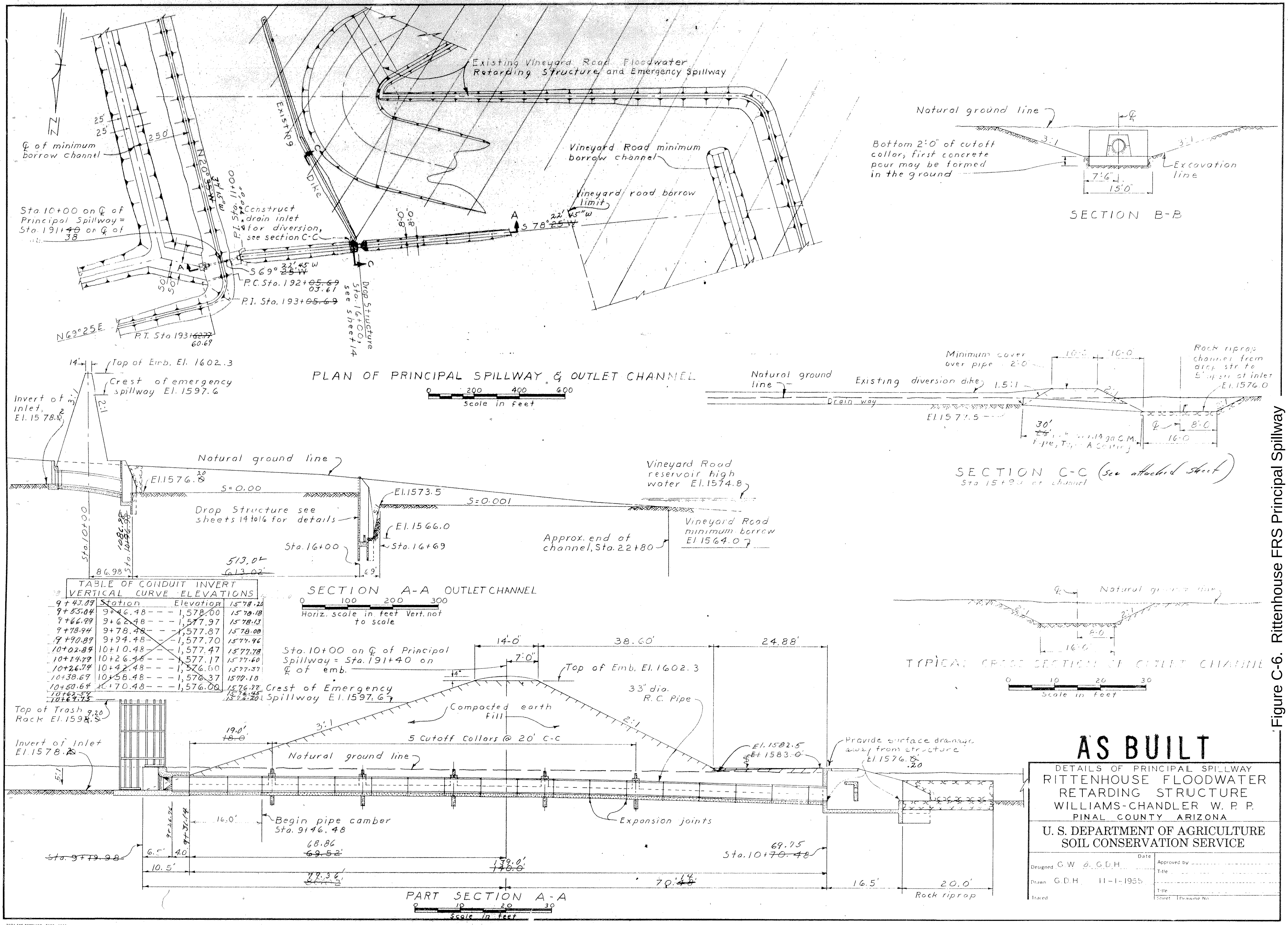


Figure C-6. Rittenhouse FRS Principal Spillway

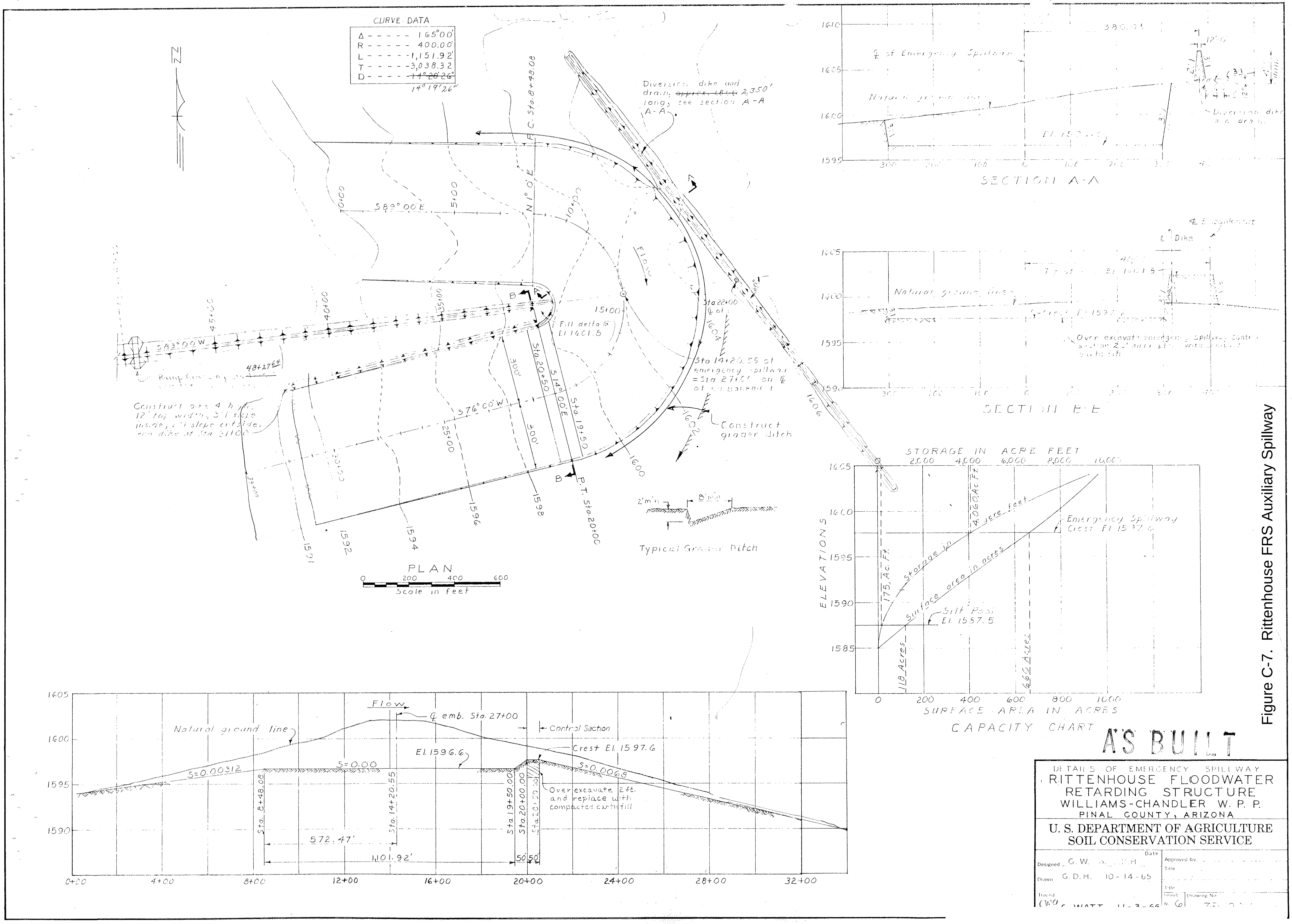
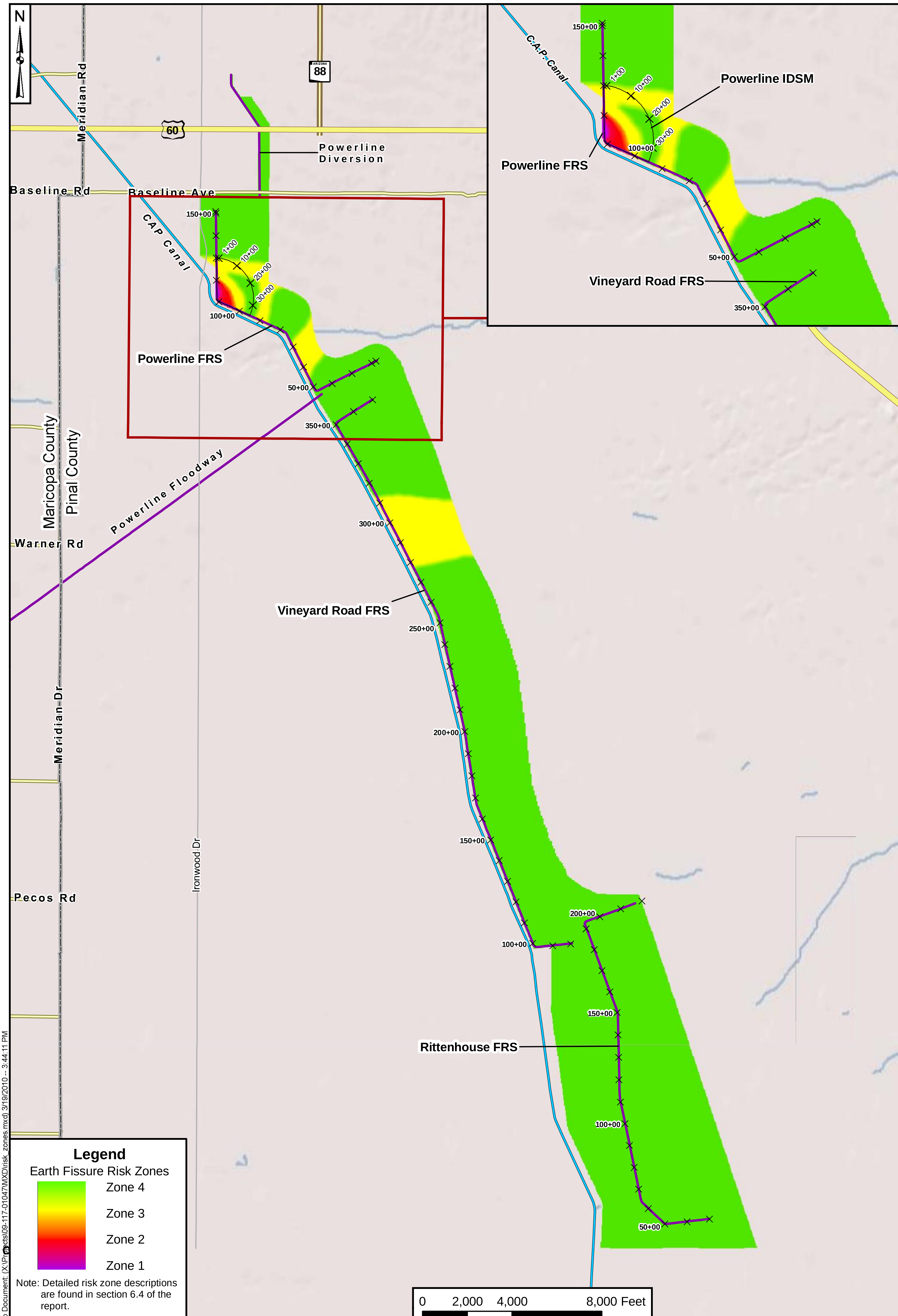


Figure C-7. Rittenhouse FRS Auxiliary Spillway



Map Document: (X:\Projects\09-117-01047\MXD\risk_zones.mxd) 3/19/2010 -- 3:44:11 PM

The map shown here has been created with all due and reasonable care and is strictly for use with AMEC Project Number: 09-117-01047. This map has not been certified by a licensed land surveyor, and any third party use of this map comes without warranties of any kind. AMEC assumes no liability, direct or indirect, whatsoever for any such third party or unintended use.

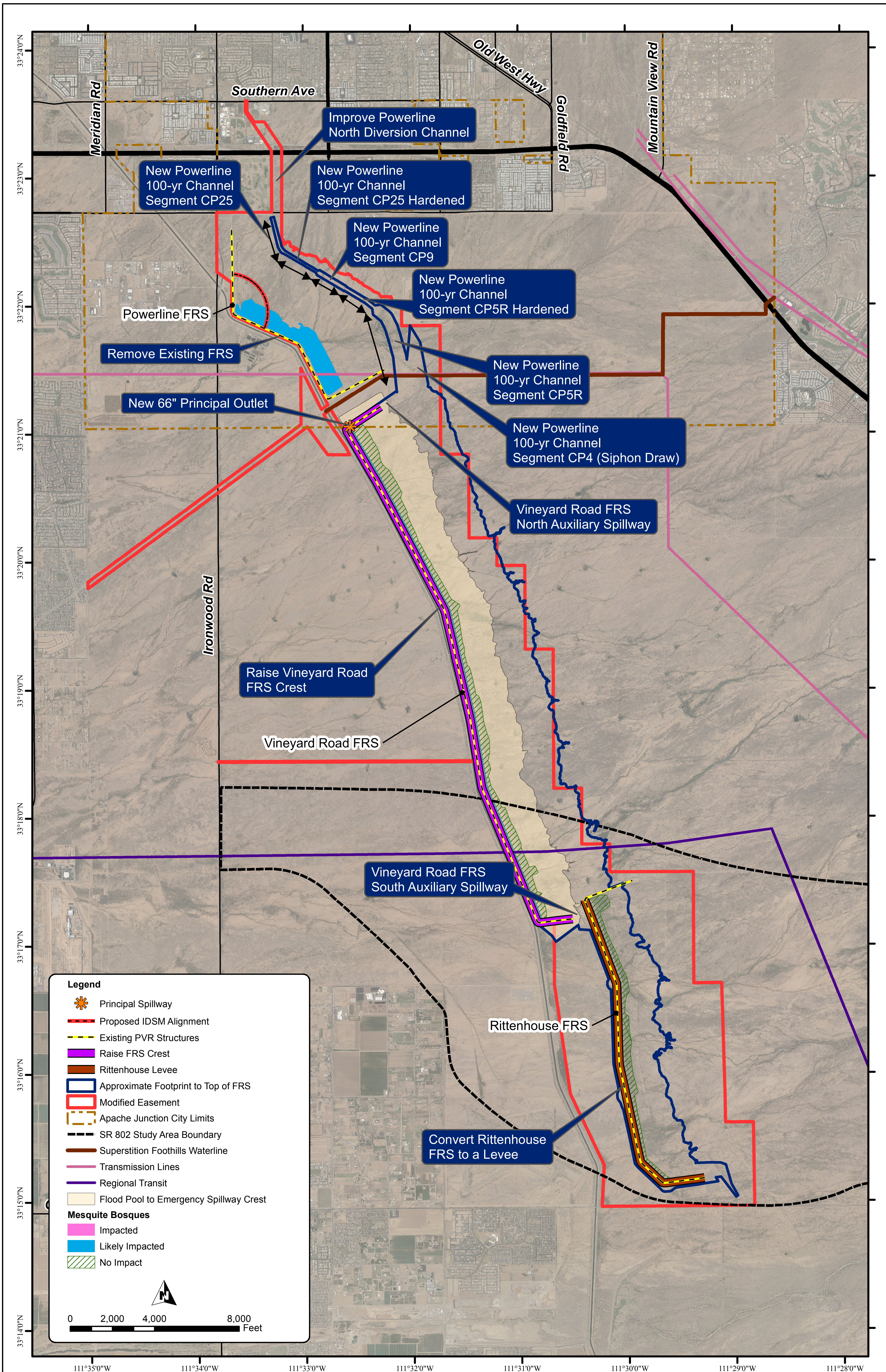
JOB NO.:	09-117-01047
DESIGN	KCF
DRAWN:	AMEC GIS
DATE:	08/2010
SCALE:	1" = 4,000'

Initial Subsidence and Earth Fissure Report Powerline, Vineyard Road, and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project Contract FCD2008C041, Work Assignment No. 2

Earth Fissure Risk Zones

FIGURE C-8

amec



DRAWING NAME

PROJECT NO. 091131019

Figure C-9: Plan View Preferred Alternative

SCALE(H): AS SHOWN
SCALE(V): N/A

DESIGNED BY: TDD
DRAWN BY: TDD
CHECKED BY: RAE

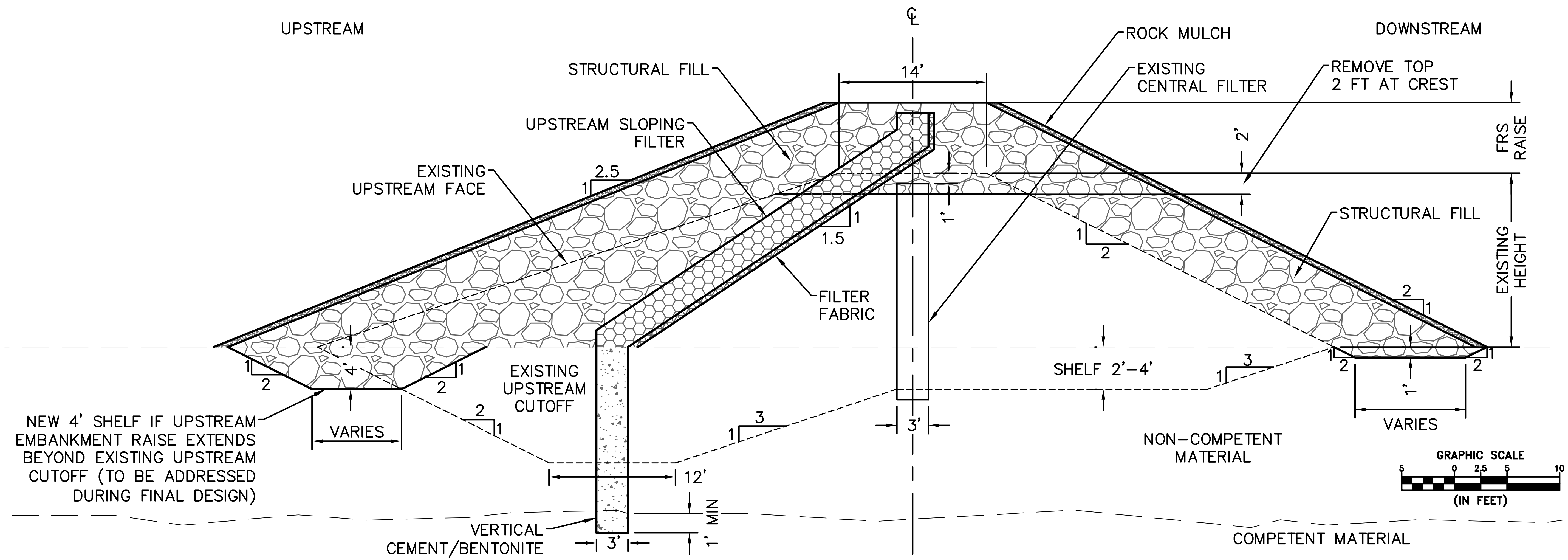
DATE: APRIL 2012

Kimley-Horn and Associates, Inc.

Engineering, Planning and Environmental Consultants

7878 North 16th Street, Suite 300
Phoenix, Arizona 85020 (602) 944-5500

NO.	REVISION	BY	DATE	APPR.



ADVANTAGES

- THE EXCAVATION OF THE UPSTREAM SLOPE CAN BE COMPLETED USING A VARIETY OF COMMONLY AVAILABLE EXCAVATORS, GRADERS AND/OR SCRAPERS.
- USE OF VERTICAL SLURRY TRENCH REDUCES THE NEED FOR EXCAVATION OF THE UPSTREAM TOE DOWN TO COMPETENT MATERIAL.
- SLURRY TRENCH CONSTRUCTION TECHNIQUES ALLOWS FOR TRENCHING THROUGH PALEO-CHANNELS AND OTHER "RUNNING" GROUND CONDITIONS IN THE FOUNDATION.
- GEOTEXTILE CAN BE LAID FLAT AGAINST THE SLOPE MAKING IT EASIER TO INSPECT AND REPAIR PRIOR TO BACKFILLING.
- REPAIRS TO DAMAGED GEOTEXTILE ARE RELATIVELY EASY REGARDLESS OF CONSTRUCTION PHASE.
- THE DISTRICT INTENDS TO UTILIZE CMAR CONSTRUCTION CONTRACTS FOR FUTURE DAM REHABILITATIONS LIKE THE PVR DAMS. THIS TYPE OF CONTRACT PROCUREMENT WILL HELP TO ASSURE QUALIFIED CONTRACTORS AS NEEDED TO PERFORM HIGH QUALITY SPECIALIZED WORK SUCH AS SLURRY TRENCHES.

DISADVANTAGES

- SURFACE PREPARATION ALONG THE UPSTREAM SLOPE WILL BE REQUIRED.
- COLLAPSE PRONE FOUNDATION SOILS REMAIN UNDERNEATH THE EXISTING UPSTREAM CUTOFF AND BELOW UPSTREAM STRUCTURAL FILL.
- INABILITY TO INSPECT SLURRY TRENCH EXCAVATION BOTTOM. VERTICAL SLURRY TRENCHING IS A SPECIALIZED CONSTRUCTION TECHNIQUE AND LIKELY WILL REQUIRE CONFIRMATION BORINGS BY THE STATE REGULATORY AGENCY.
- GEOTEXTILE EXPOSURE TIME MAY BE MORE DIFFICULT TO CONTROL. BACKFILLING OVER THE GEOTEXTILE TO THE FULL HEIGHT OF THE STRUCTURE MAY TAKE SEVERAL DAYS DEPENDING ON CONSTRUCTION SEQUENCING.
- DOWNSTREAM STRUCTURAL FILL IS FOUNDED ON COLLAPSIBLE FOUNDATION SOILS.
- ADDITIONAL RIGHT-OF-WAY REQUIRED FOR DOWNSTREAM RAISE.

- A SIMILAR ALTERNATIVE (1A(I)) WITH AN UPSTREAM FLOWABLE FILL CUT-OFF TRENCH SCORED LOWER IN AN ALTERNATIVES ANALYSIS THAN AN ALTERNATIVE (1A(II)) THAT FULLY REMOVED THE UPSTREAM NON-COMPETENT MATERIALS (URS 2004).

OUTSTANDING CONCERNS

- UNKNOWN PERFORMANCE RELATED TO CRACKING OF SLURRY BACKFILL AND THE POTENTIAL FOR LEAKAGE THROUGH A CRACK IN THE SLURRY BACKFILL WHICH CAUSES COLLAPSE OF THE NON-COMPETENT FOUNDATION MATERIAL CREATING A VOID BELOW THE DAM DOWNSTREAM OF THE CUT-OFF.
- UPSTREAM VERTICAL CEMENT/BENTONITE CUT-OFF HAS NOT BEEN WELL VETTED THROUGH MULTIPLE FMEAS UNLIKE THE FULL UPSTREAM SLOPING FILTER ALTERNATIVE. A FINAL DESIGN FMEA ON THIS ALTERNATIVE IS RECOMMENDED.
- OTHER SLURRY TRENCH BACKFILL MATERIALS SHOULD BE CONSIDERED DURING FINAL DESIGN TO OPTIMIZE COST SAVINGS AND/OR PERFORMANCE.
- MORE THAN 10 YEARS OF PROFESSIONAL PRACTICE ASSESSING ALTERNATIVES TO MITIGATE CRACKED FRS STRUCTURES IN NON-FISSURE RISK ZONES HAS DEVELOPED THE FULL UPSTREAM SLOPING FILTER REHABILITATION ALTERNATIVE. IN GENERAL THE UPSTREAM SLOPING FILTER ALTERNATIVE FITS MOST UNIQUE SITE CONDITIONS AND MITIGATES ALL IDENTIFIED FAILURE MODES. NEVERTHELESS, THE PVR PROJECT PRESENTS ITS OWN UNIQUE FEATURES ASSOCIATED WITH THE UPSTREAM FRS CUT-OFF WHICH HAS POSITIVE QUALITIES THAT CAN BE COMBINED WITH A CUT-OFF.
- CUT-OFF TRENCH MAY NEED TO BE CONSERVATIVELY DEEPENED (DESIGN DEPTH) TO COMPENSATE FOR THE ABILITY TO NOT INSPECT THE FOUNDATION SOILS TO VERIFY PENETRATION INTO THE UNDERLYING COMPETENT FOUNDATION SOILS.
- LIMITED EXPERIENCE WITH CONSTRUCTION OF A VERTICAL SLURRY TRENCH IN DISTRICT FRS DAMS.
- USE OF ALTERNATIVE DELIVERY CONSTRUCTION CONTRACTS MAY ALLOW FOR MORE DETAILED GEOTECHNICAL INVESTIGATIONS DURING CONSTRUCTION TO BETTER CHARACTERIZE SUBSURFACE CONDITIONS ALLOWING THE USE OF OPEN-CUT EXCAVATIONS FOR THE CUT-OFF TO REDUCE COSTS.

Kimley-Horn and Associates, Inc.

Figure C-10. Preferred Alternative Vineyard Road FRS – Typical Section

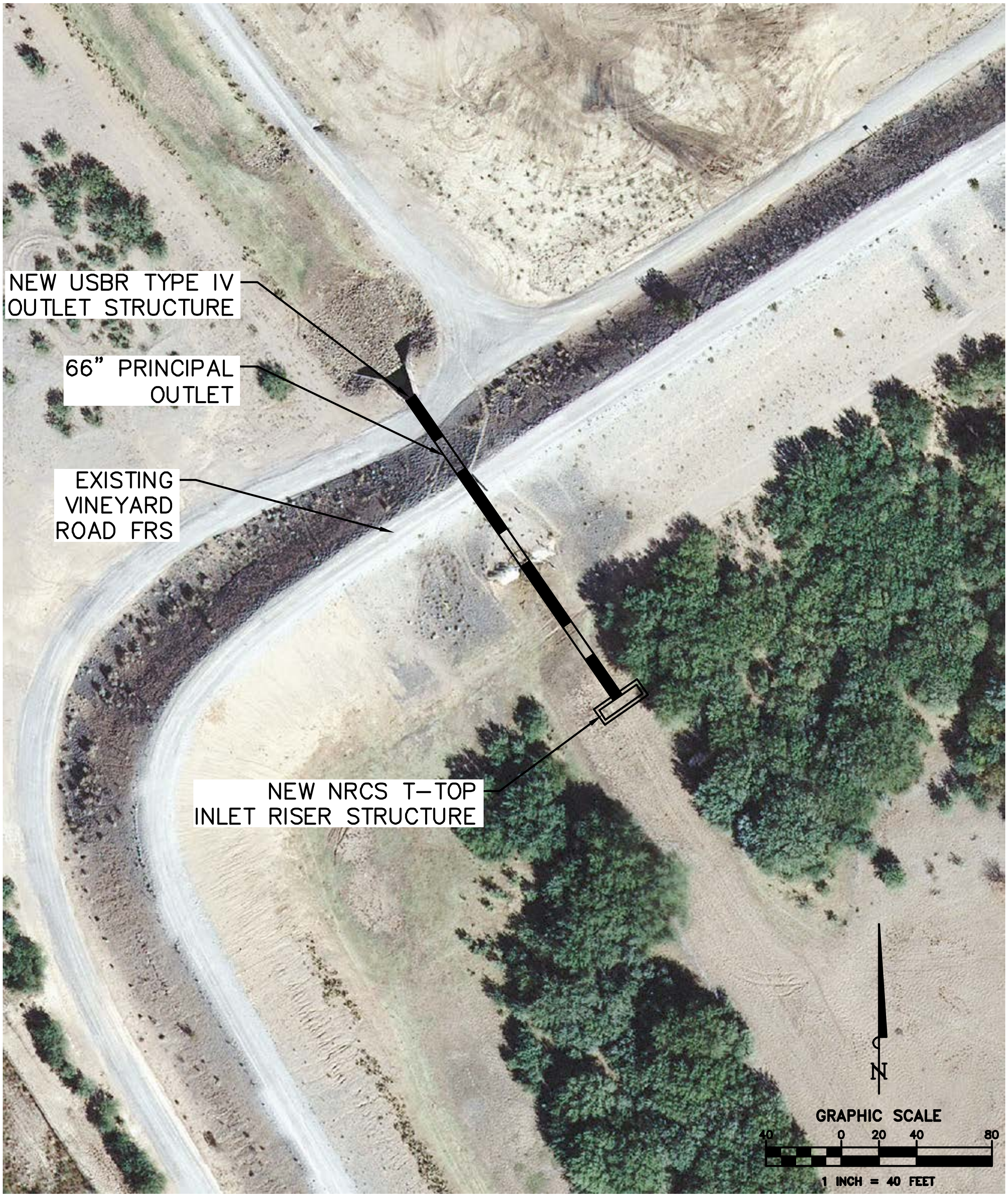


FIGURE C-11: PREFERRED ALTERNATIVE – VINEYARD ROAD FRS PRINCIPAL SPILLWAY

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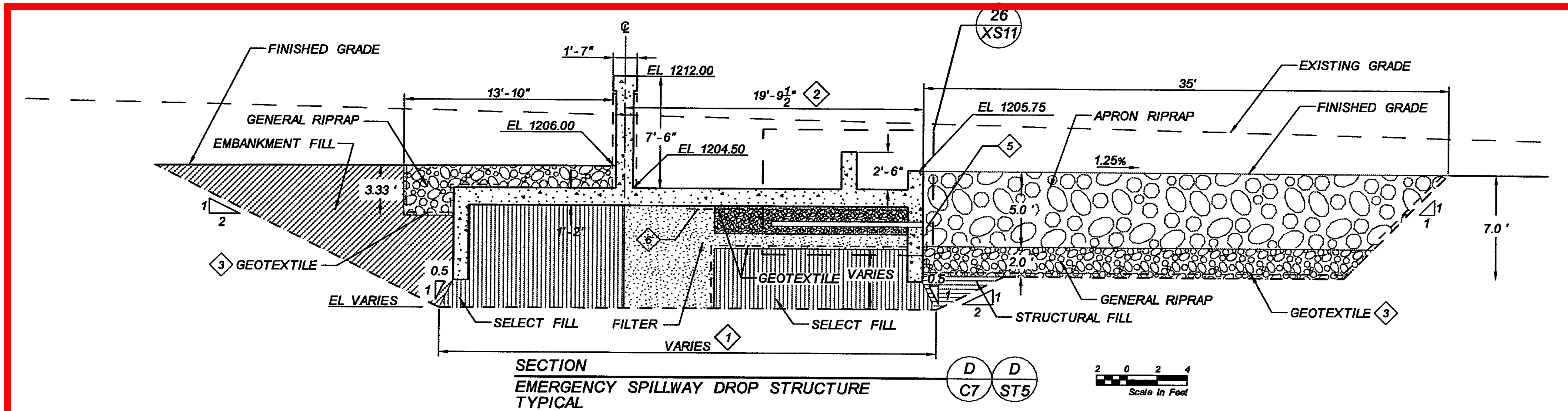
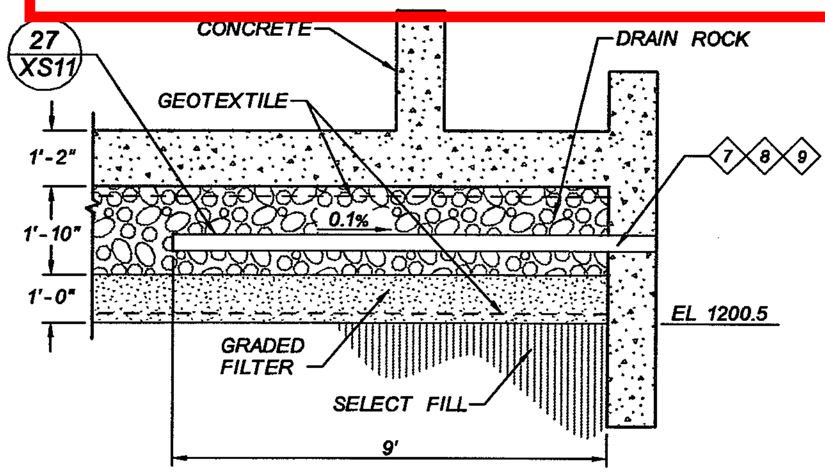
XREFS:

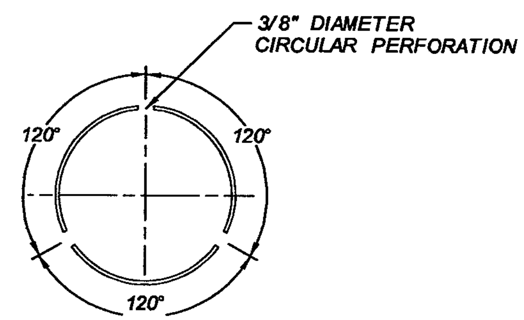
Kimley-Horn and Associates, Inc.



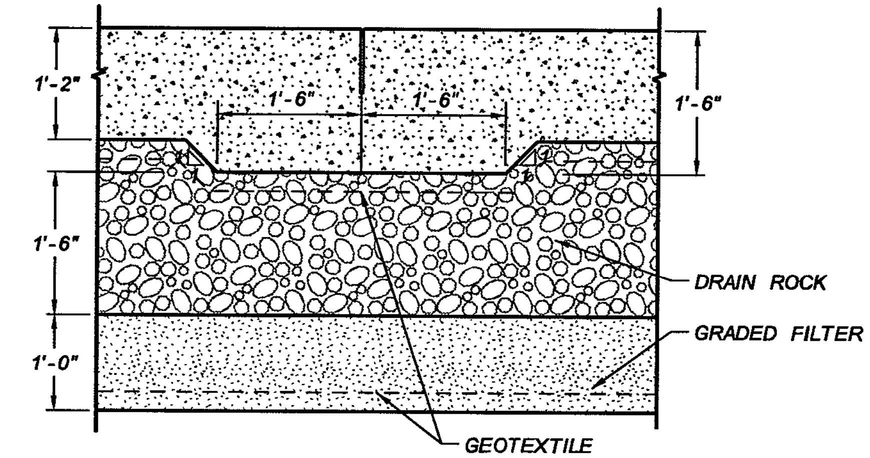
SECTION
EMERGENCY SPILLWAY DROP STRUCTURE
TYPICAL
D C7 D ST5



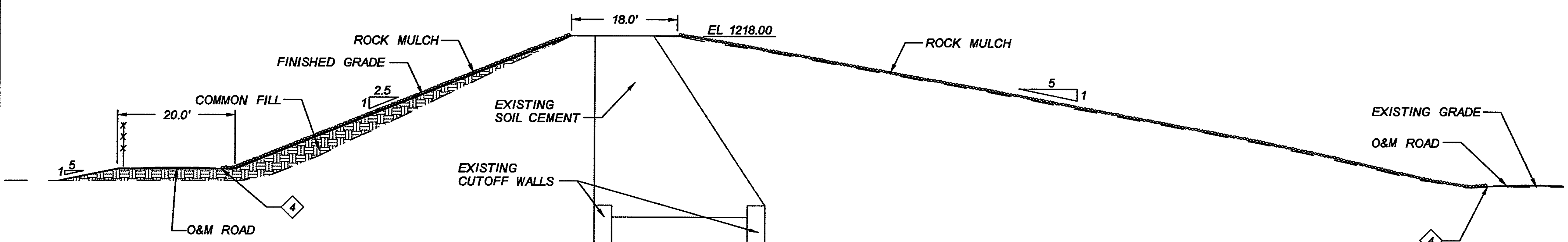
DETAIL
DRAIN PIPE
27 XS11



DETAIL
PIPE PERFORATIONS (NTS)
27 XS11



DETAIL
GRADED FILTER
25 ST5



SECTION
EXISTING FISSURE RISK ZONE
GENERAL GRADING
TYPICAL SECTION
G C10

KEY NOTES

1. THE MINIMUM EXCAVATION LIMITS BELOW THE SPILLWAY ARE DETERMINED BY EXTENDING A 0.5:1 SLOPE FROM THE BOTTOM OUTSIDE EDGE OF CONCRETE TO THE REQUIRED EXCAVATION DEPTH AS SHOWN ON DRAWING C2.
2. STILLING BASIN LENGTH AS SHOWN IS MEASURED FROM THE CENTERLINE.
3. END GEOTEXTILE 6 INCHES FROM FINISHED GRADE.
4. EXTEND ROCK MULCH TO END OF O&M ROAD.
5. EXTEND GEOTEXTILE 2 FEET BEYOND CORNER.
6. PLACE GEOTEXTILE OVER FILTER AND DRAIN MATERIAL. GEOTEXTILE TO STOP 4 FT FROM UPSTREAM EDGE OF FILTER.
7. 4 INCH DIA. SCH 40, PVC PIPE, 3/8 INCH CIRCULAR PERFORATIONS, 18 PERFORATIONS PER FOOT, PVC PLUG OR CAP AT UPSTREAM END WITH PERFORATIONS.
8. INSTALL 3 PIPES PER PANEL. ONE PIPE SHALL BE LOCATED AT THE CENTER, WITH 2 OTHER PIPES LOCATED ON EACH SIDE 9 FEET FROM CENTER.
9. DRAIN PIPE INVERT ELEVATION AT TOE WALL SHALL BE 1202.0 FEET.

Figure C-12. Preferred Alternative – Vineyard Road FRS Auxiliary Spillway Cross Section

GENERAL NOTES

SECTIONS WERE UPDATED TO REFLECT CHANGES IN CONCRETE AND DRAIN DESIGN

TWO WORKING DAYS BEFORE YOU DIG, CALL 263-1100 BLUE STAKE

NO.	REVISION	BY	DATE
2	ADDED KEY NOTE 9	TER	10-09
1	REVISED PER AGENCY COMMENTS	TER	9-09

ADWR APPROVAL

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
ENGINEERING DIVISION

WHITE TANKS FRS NO 3
REMEDIATION PROJECT - PHASE 2
PCN 470.04.30, FCD CONTRACT NO. 2008C031

	BY	DATE
DESIGNED	MSJ	10-09
DRAWN	JEO, KLP	10-09
CHECKED	TER	10-09

Registered Professional Engineer 32847 TODD E. RINGSMUTH ARIZONA, USA EXPIRES 09-30-2010

URS 7720 NORTH 16TH STREET SUITE 100 PHOENIX, AZ 85020

DRAWING NO. XS11 | EVERGENCY SPILLWAY AND EMBANKMENT TYPICAL SECTION | SHEET 43 OF 78

P:\FCDMC\23444295 WT3 Phase 2\CADD\SHEETS\REV-2\WT3_XS11-P2-REV2.dgn

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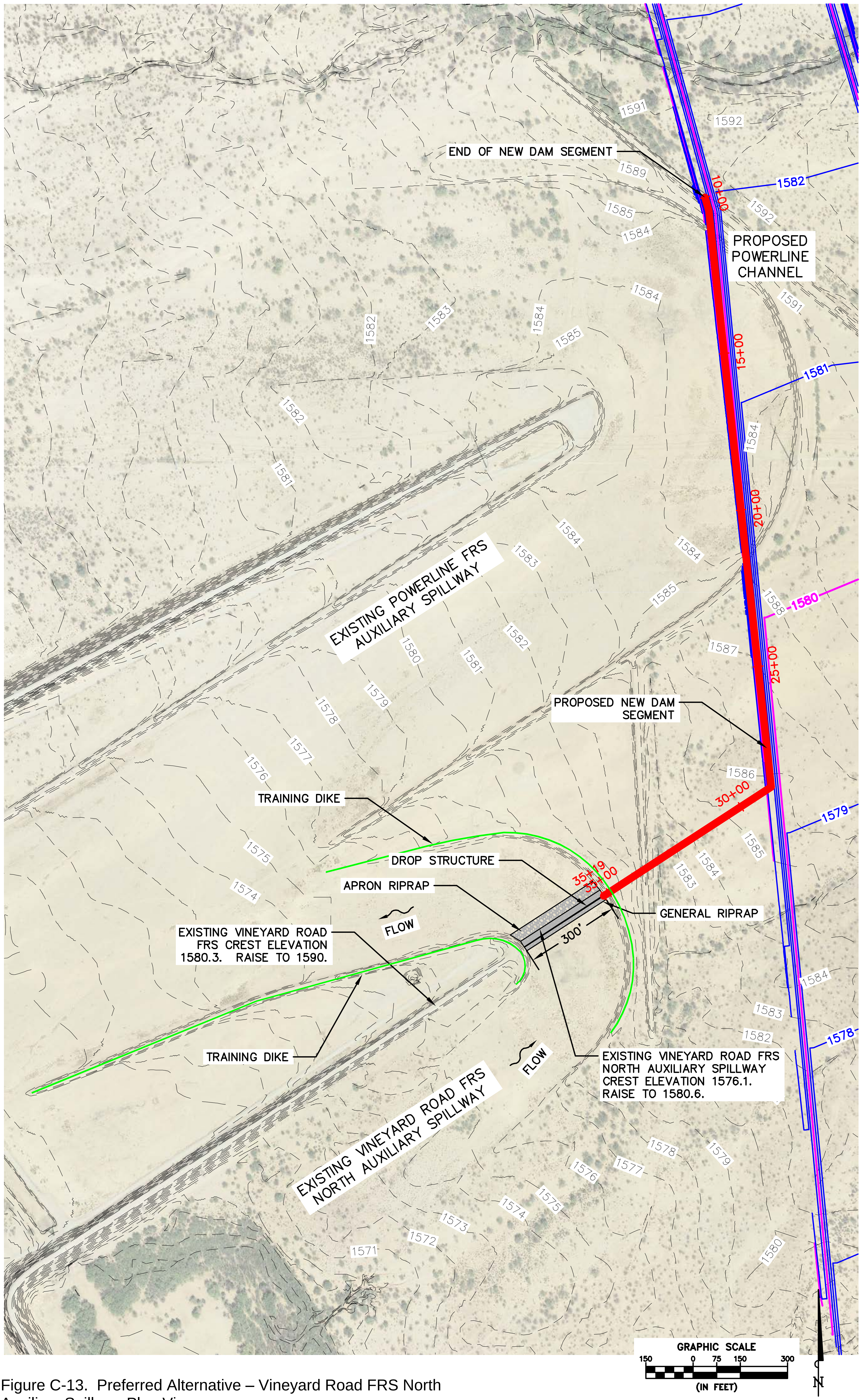

Figure C-13. Preferred Alternative – Vineyard Road FRS North Auxiliary Spillway Plan View

Kimley-Horn and Associates, Inc.

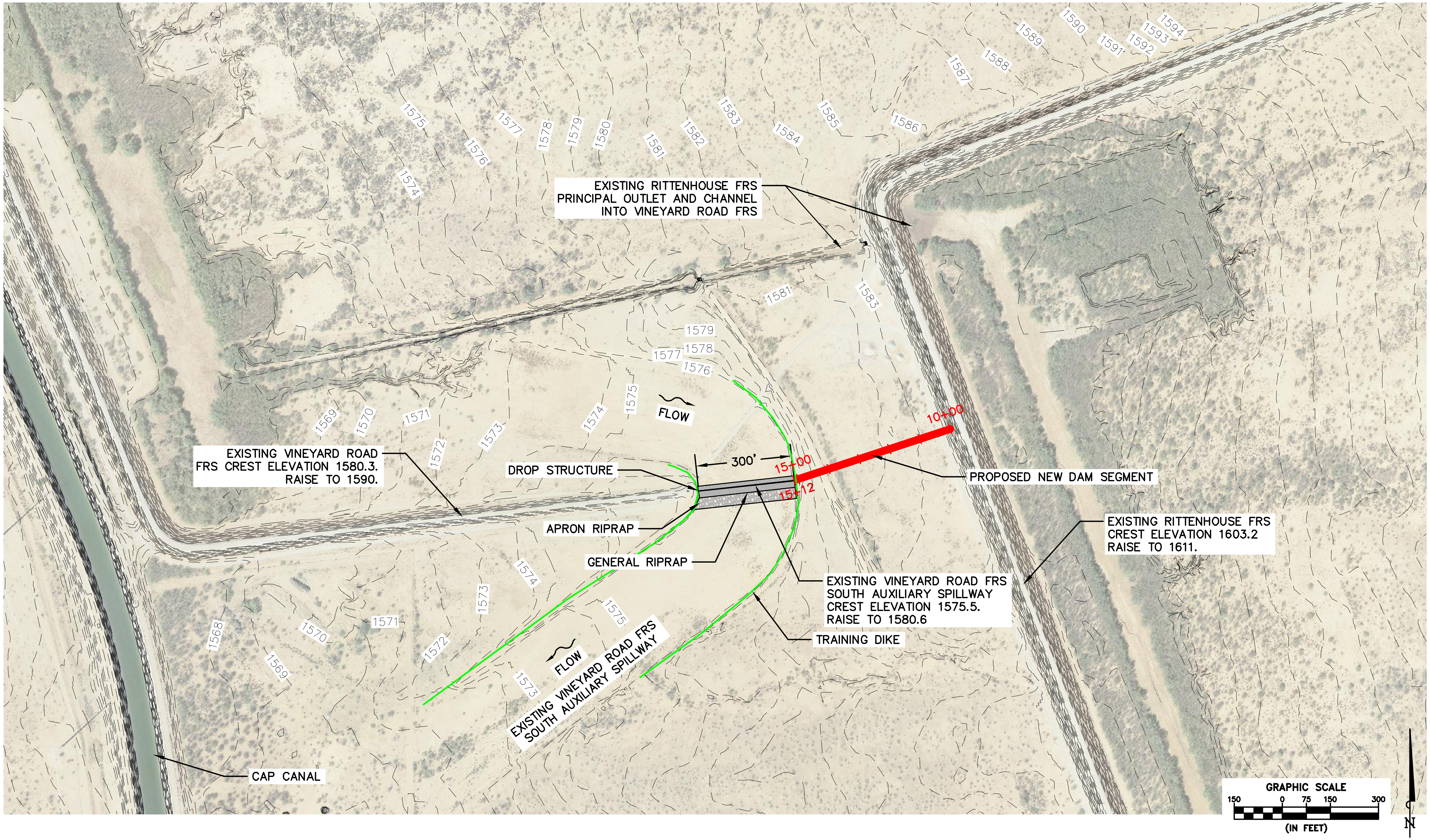

Figure C-14. Preferred Alternative – Vineyard Road FRS South Auxiliary Spillway Plan View

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XREFS:

Kimley-Horn
and Associates, Inc.

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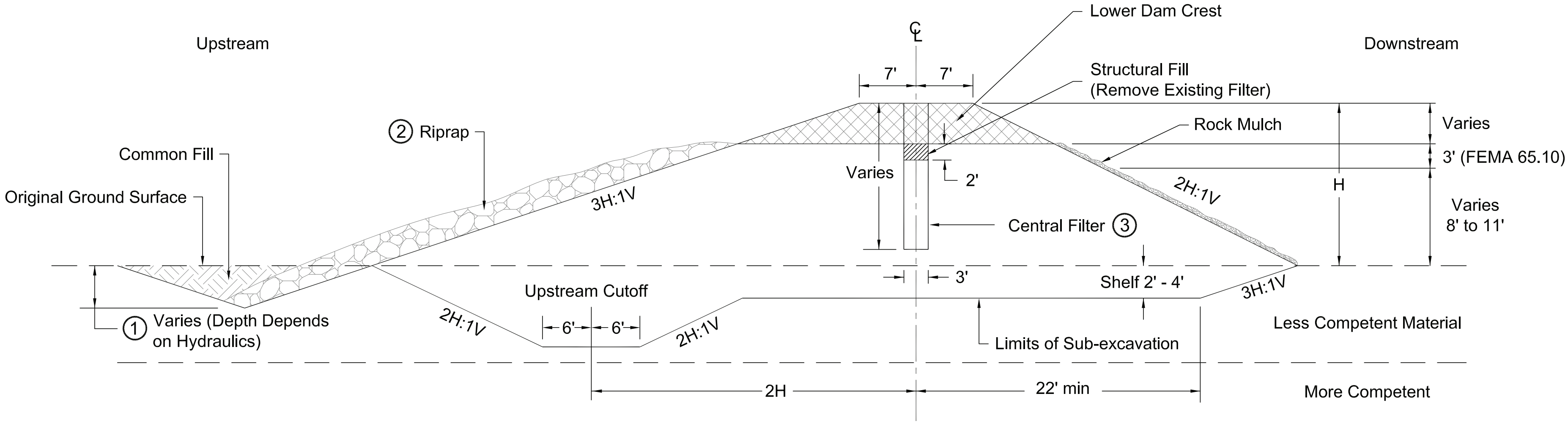


Notes:

1. Depth of over excavation to be determined by modeling during final design. Assume 5' bgs for planning cost estimates.

2. Riprap to be sized for expected flow velocities. Toe down in accordance with anticipated scour. Underlay riprap with geotextile fabric.

3. Central filter extends from Stations 80+00 to 210+00; there is no filter between Stations 30+00 to 80+00. The filter does not extend through the embankment into native soils.

Based on As-Built plans for the Rittenhouse FRS (SCS, 1968, 1978)

JOB NO.	17-2010-4029
DESIGN:	BAH/LAH
DRAWN:	GWH
DATE:	12/2011
SCALE:	1" = 20'

Figure C-15. Preferred Alternative
Rittenhouse Levee – Typical Section

CONTRACT FCD 2008C041
POWERLINE, VINEYARD ROAD & RITTENHOUSE FRS
REHABILITATION OR REPLACEMENT PROJECT
WORK ASSIGNMENT NO.3

amec

Figure C-16: Emergency Spillway Inundation Areas - Vineyard Road FRS

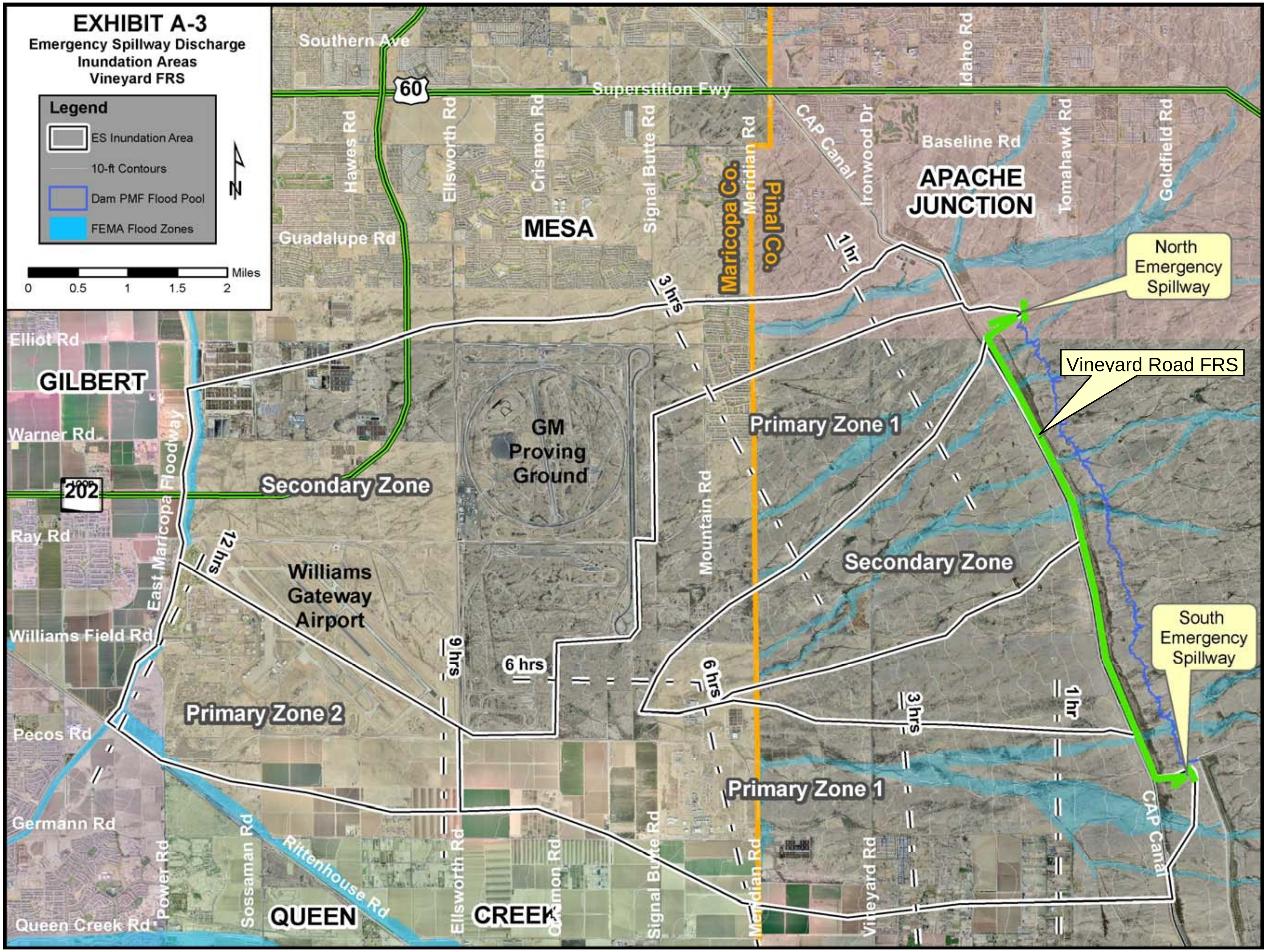


Figure C-17: Dam Failure Inundation Areas - Vineyard Road FRS

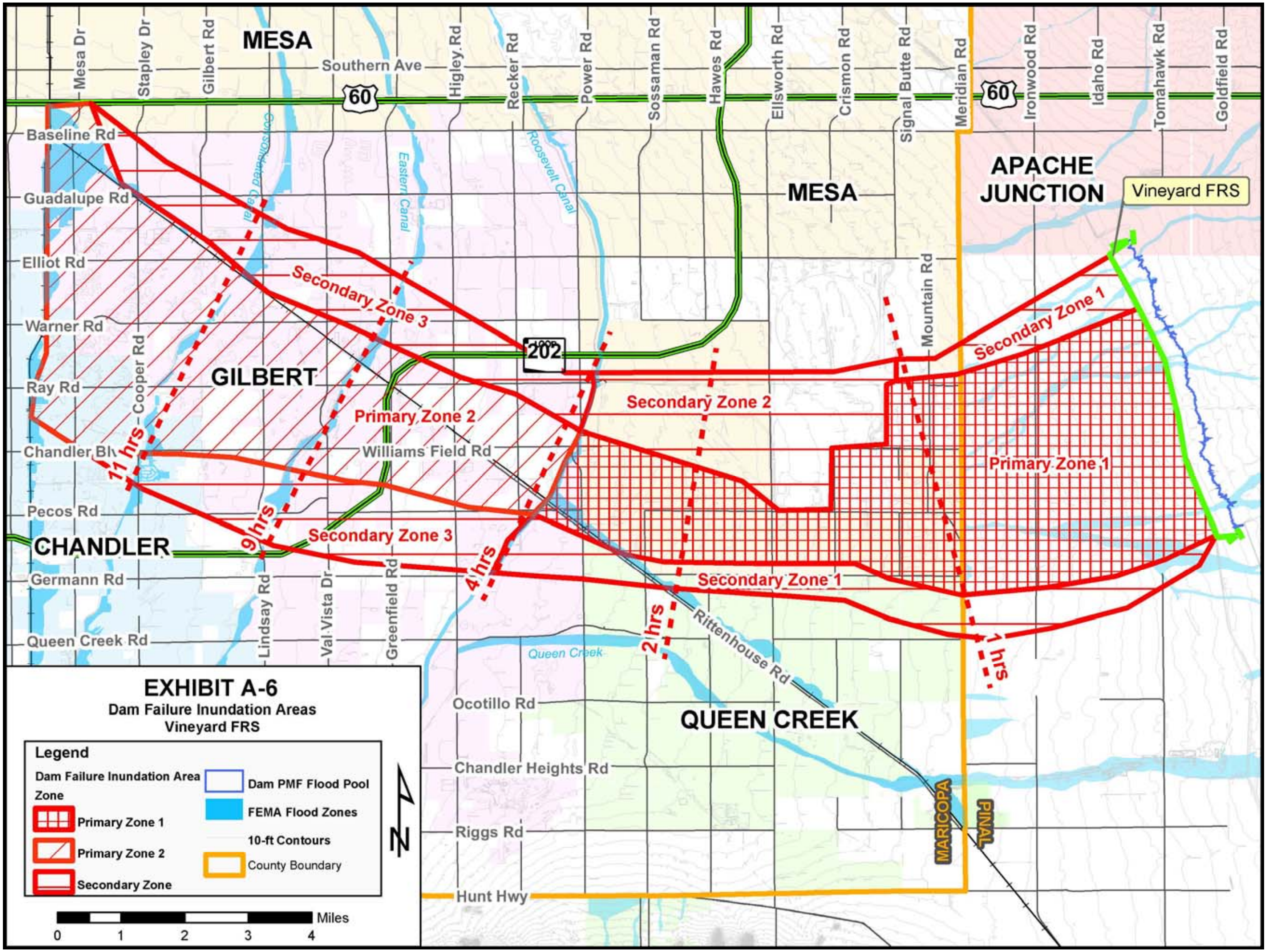


Figure C-18: Emergency Spillway Inundation Areas - Rittenhouse FRS

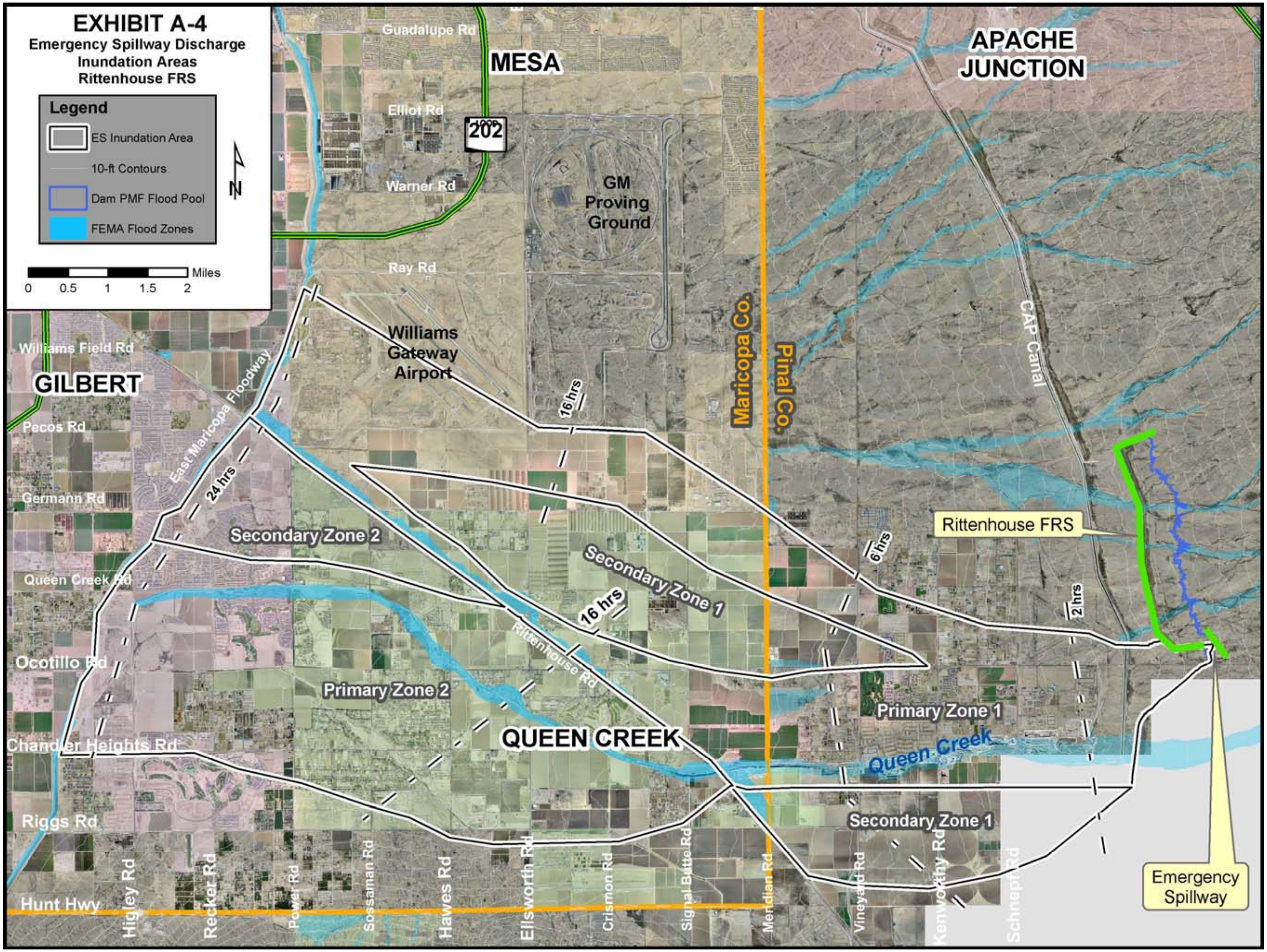
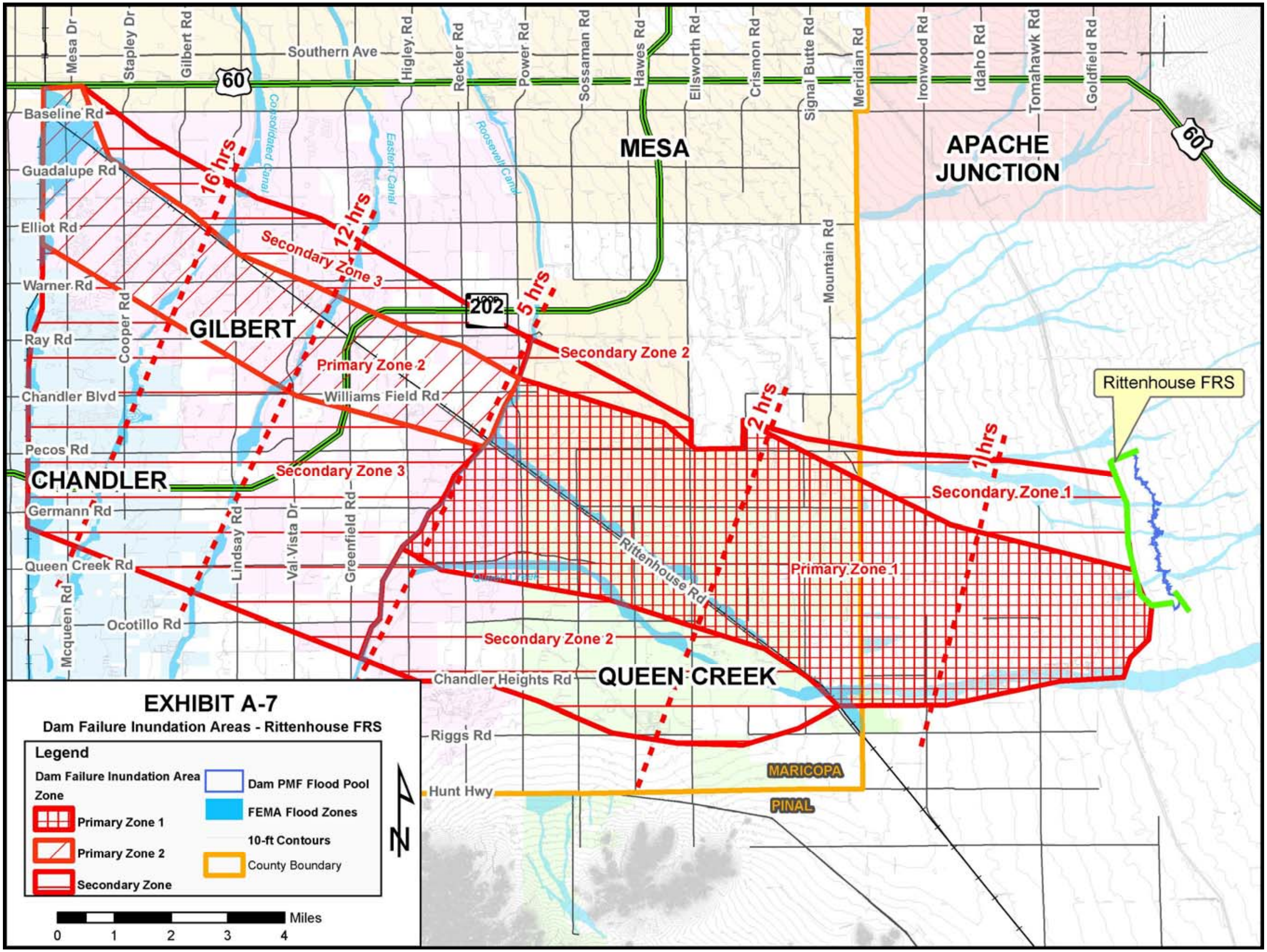


Figure C-19: Dam Failure Inundation Areas - Rittenhouse FRS



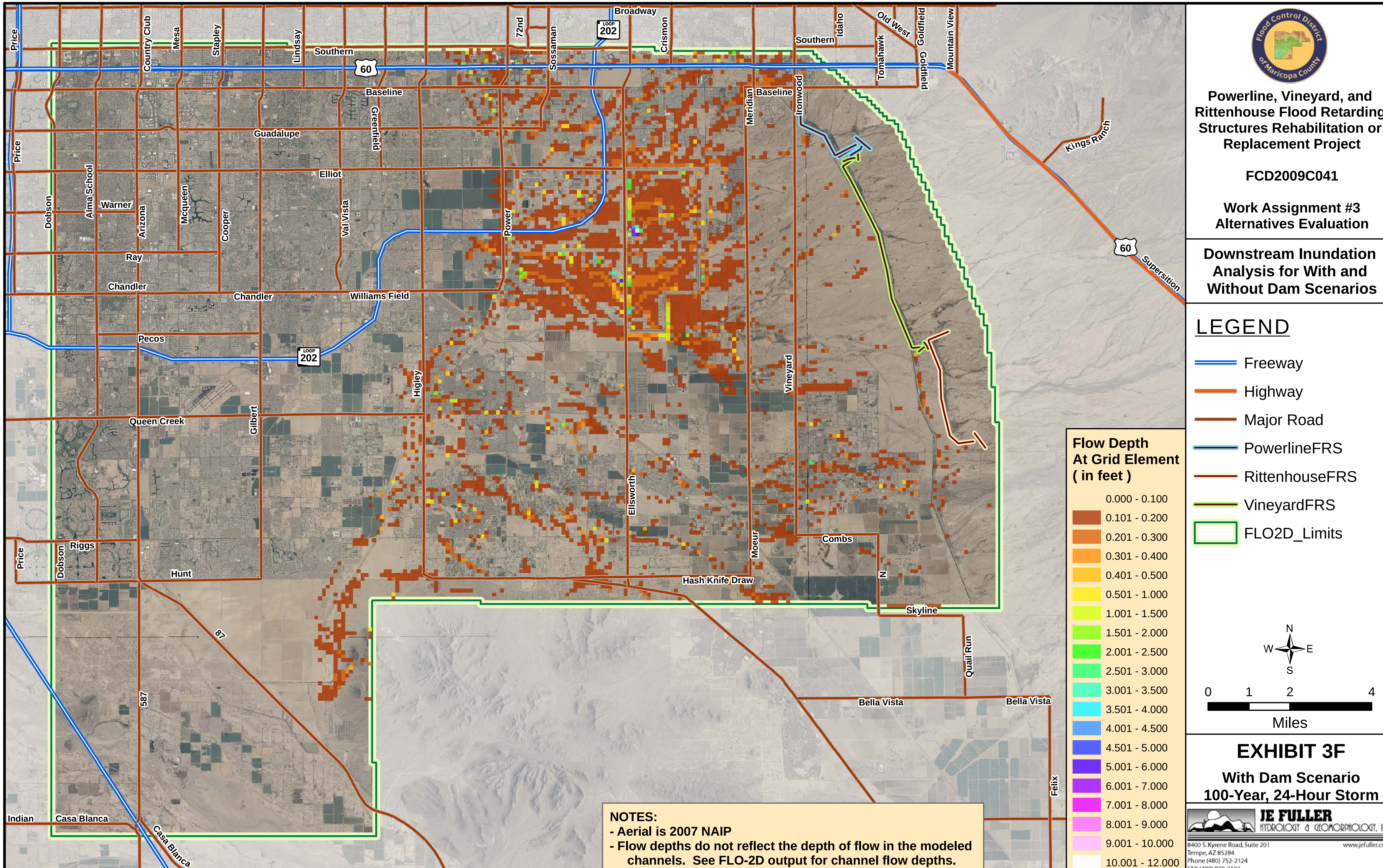
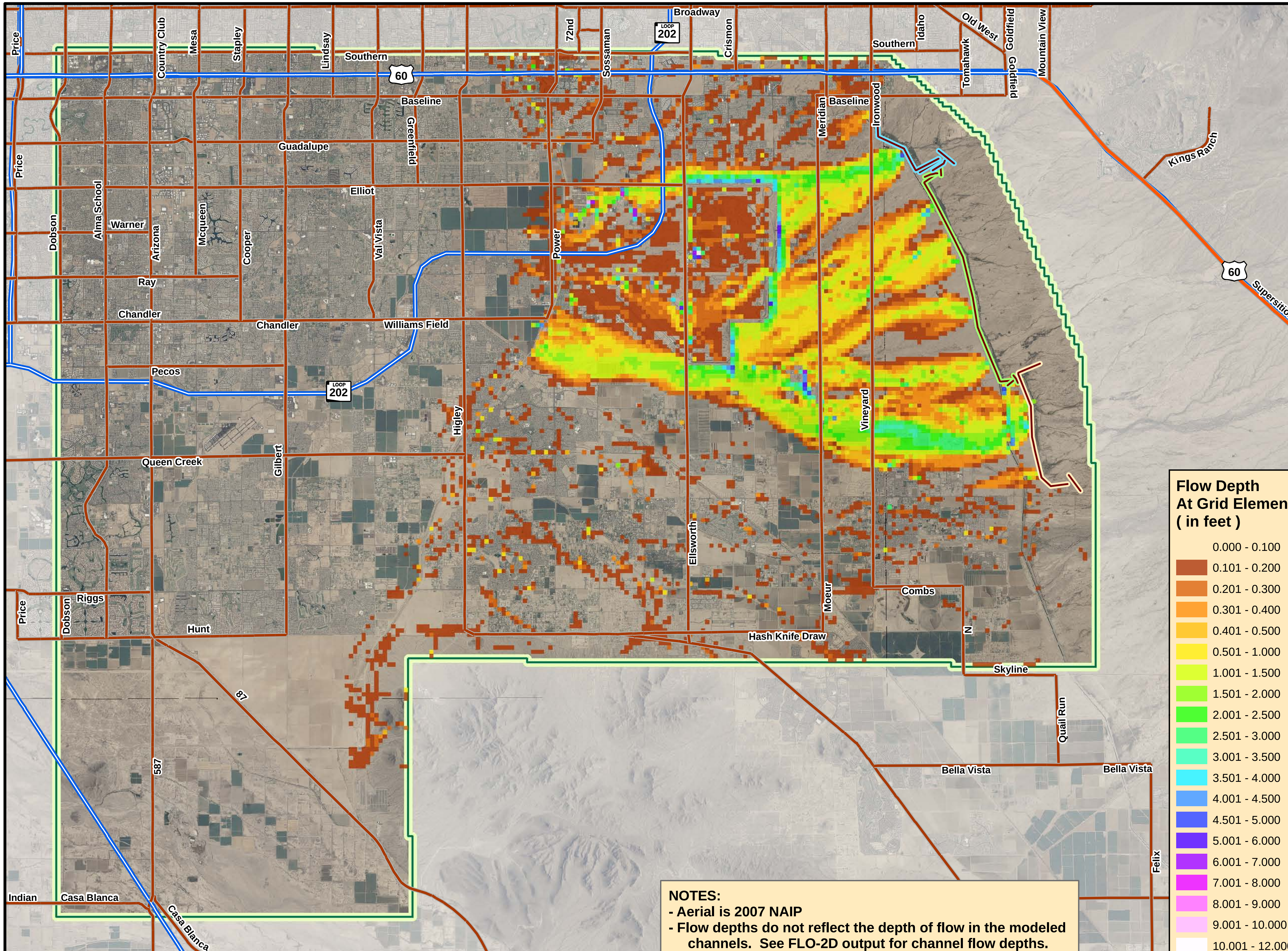


Figure C-20. 100-year Floodplain Mapping With Dams In-Place



Flood Control District of Maricopa County

Powerline, Vineyard, and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project

FCD2009C041

Work Assignment #3
Alternatives Evaluation

Downstream Inundation Analysis for With and Without Dam Scenarios

LEGEND

Freeway
Highway
Major Road
PowerlineFRS
RittenhouseFRS
VineyardFRS
FLO2D_Limits

N W E S

0 1 2 4
Miles

EXHIBIT 4F

Without Dam Scenario
100-Year, 24-Hour Storm

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC
8400 S. Kyrene Road, Suite 201
Tempe, AZ 85284
Phone (480) 752-2124
FAX (480) 839-2193
www.jefuller.com

Figure C-21. 100-year Floodplain Mapping Without Dams In-Place

Appendix D Investigation and Analyses Report

APPENDIX D

INVESTIGATIONS AND ANALYSES REPORT

VINEYARD ROAD AND RITTENHOUSE FLOOD RETARDING STRUCTURES

SUPPLEMENTAL WATERSHED PLAN AND

ENVIRONMENTAL ASSESSMENT

DRAFT

Prepared by:
Kimley-Horn and Associates, Inc.

For the:
Flood Control District of Maricopa County
FCD2008C042

In cooperation with:
Natural Resources Conservation Service
US Department of Agriculture

TABLE OF CONTENTS

1. INTRODUCTION

The Vineyard Road and Rittenhouse Flood Retarding Structures (FRS) were constructed by the Soil Conservation Service (now the Natural Resources Conservation Service – NRCS) in 1968 and 1969, respectively, as part of the Williams-Chandler Watershed Protection and Flood Prevention Project. The flood retarding structures are operated and maintained by the Flood Control District of Maricopa County (District). Vineyard Road FRS, a 5.5 mile long, 16.5 foot high earth dam, and Rittenhouse FRS, a 3.6 mile long, 24.3 foot high earth dam, provides flood protection to downstream residents, structures, and infrastructure.

The FRSs have developed safety deficiencies and both dams are approaching on the original 50-year project lifetimes. The embankments of the dams are experiencing longitudinal and transverse cracking and the auxiliary spillways for each dam do not have the capacity to pass the inflow design flood. In 2009, the District requested Federal planning and implementation assistance for long-term solutions to the identified dam safety deficiencies. The rehabilitation of the structures will require raising the dams with earthfill, replacing the existing principal spillways with new risers and outlets, installing new embankment filters, raising the crest of the auxiliary spillways, and providing structural auxiliary spillways. This Supplemental Watershed Plan and Environmental Assessment (Plan/EA) determines the feasibility of rehabilitation the FRSs to provide for continued flood protection while meeting current applicable local, State, and Federal regulations

The above information is presented as the investigations, studies, and reports for the Powerline, Vineyard Road and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project was conducted on a joint approach rather than on the individual dams and watersheds. The following sections below are summaries of those studies and reports for the PVR project

2. HYDROLOGY AND HYDRAULICS

This section of the "Investigations and Analysis Report" provides a summary of the hydrologic and hydraulics analysis in previous investigations as well as studies conducted by Kimley-Horn for the PVR project.

2.1 Previous Studies

Previous existing conditions of the PVR FRS watersheds have been studied as part of the following investigations:

- "Desert Drive Area Study Existing Conditions Hydrology" (DDA Existing Conditions Hydrology) by the Arizona State Land Department (ASLD, 2007)
  - The Arizona State Land Department conducted an existing conditions hydrology study for an area of State Lands known as Desert Drive Area (DDA). The Desert Drive Area study includes the PVR structures and their contributing watersheds. The purpose of the hydrology study was to determine the rainfall runoff response for the Desert Drive Area under existing conditions.
  - HEC- 1 models were developed for the l00-year, 200-year, 500-year, and PMF storm events. The 100-year, 200-year and 500-year storm events were analyzed for 6-hour and 24-hour storm durations. The PMF storms were analyzed for the 6-hour and 72-hour storms. For the Desert Drive Area downstream of the PVR structures, only the 100-year, 6-hour and 24-hour models were developed.
- "Desert Drive Area Study Existing Conditions Inundation and Sedimentation Analysis for PVR Structures (DDA Inundation and Sedimentation) by the Arizona State Land Department (ASLD 2008).
  - This is Volume II of the Desert Drive Area study. This study utilized FLO-2D software to create a two dimensional model of the discharges entering the PVR structures. The FLO-2D model was completed in order to evaluate the interconnected character of the PVR Structures and to determine the existing condition inundation limits of the structures for the 100-year, 24-hour storm and the 6-hour and 72-hour PMF events (full and half). The results of the analysis provide overtopping depths and durations for each of the storms evaluated.

2.2 Hydrologic Design Criteria

The rehabilitation or replacement of the PVR structures must meet the most critical design criteria between NRCS, ADWR and District hydrologic design criteria. The project must meet both District and NRCS requirements for flood protection and District, NRCS and ADWR requirements for dam safety. NRCS design criteria, flood protection, and dam safety requirements are documented in "Earth Dams and Reservoirs," Technical Release No. 60, dated July 2005. ADWR design criteria and dam safety requirements are documented in the "Arizona Administrative Code Title 12, Chapter 15, Article 12 – Dam Safety Procedures" dated June 12, 2000.

Per NRCS criteria for High Hazard Dams, the principal spillway design flood is the 100-year and 10-day storm, and the principal spillway must have: a) the capacity to prevent the auxiliary spillway from functioning more frequently than the 100 year event. ADWR requires that the principal spillway has capacity to evacuate 90% of the storage capacity in 30 days, excluding reservoir inflows.

The NRCS auxiliary spillway design flood is based on the stability design hydrograph and freeboard hydrograph. The stability design hydrograph is based on the 100-year 6-hour event and the 6-hour PMP. The freeboard hydrograph is the hydrograph resulting from the critical PMP. The auxiliary spillway must have the capacity to pass the stability design hydrograph at safe velocity and pass the freeboard hydrograph with a water surface at or below the top of the dam (no freeboard). The ADWR auxiliary spillway design flood and inflow design flood (IDF) will range from 0.5 to the full PMF, with size increasing based on the persons at risk and the potential for downstream damage. The auxiliary spillway capacity must be sufficient to pass the IDF plus freeboard requirements, which (for new or unsafe dams) require the largest of: a) the sum of the IDF maximum water depth above the spillway crest plus wave run up; b) the sum of the IDF maximum water depth of the spillway crest plus 3 feet; or c) a minimum of 5 feet from the auxiliary spillway crest to the dam crest.

NRCS stability design requirements include that the auxiliary spillway maximum stress limitations must not be exceeded for the stability design hydrograph. The integrity of the spillway must also be evaluated to ensure the spillway will not breach (headcut will not advance beyond the upstream edge of the level part of the inlet channel) during passage of the freeboard hydrograph.

2.3 Probable Maximum Precipitation/Probable Maximum Flood

Kimley-Horn prepared the “Final PMP Technical Memorandum” (Kimley-Horn, 2010) to provide a planning level recommendation of the anticipated percent reduction in probable maximum precipitation (PMP) rainfall depths when using a site-specific approach compared to traditional HMR-49 methods. Kimley-Horn calculated the HMR-49 PMP values for each individual structure watershed rather than as a whole for all three structures. Based on the available results and findings of the Magma FRS site specific studies and the relatively close proximity of the dam to the PVR structures, Kimley-Horn recommended a percent reduction of 10%, 30% and 25% for the 6-, 24-, and 72-hour storms, respectively.

The recommended planning level PMP was input into PVR FRSs HEC-1 models to develop the planning level PMF for each structure. The controlling storm for the PVR structures, based on this analysis, is the 6-hr PMP local storm. .

2.4 Existing and Future Conditions Hydrology and Hydraulics Update

Kimley-Horn prepared the “Existing and Future Conditions Hydrology and Hydraulics Update Technical Report” (Kimley-Horn, 2010) to document hydrologic and hydraulic updates for existing and future land use conditions associated with each FRS. The results of the hydrology and hydraulics study provide baseline conditions for the three structures.

Multi-frequency inflow hydrographs were developed for the existing and future conditions 100-year, 6-hour and the 2-, 5-, 10-, 25-, 50-, 100- and 500-year, 24-hour storms, and the 6-hour, 24-hour and 72-hour probable maximum flood (PMF).

2.5 Level Pool Analysis Results

Powerline FRS experiences no flow in the auxiliary spillway for any of the existing conditions multi-frequency (2 yr through 500 yr) events. The future conditions land use for Powerline FRS results in auxiliary spillway flow only during the 500-year, 24-hour storm event at a depth of 0.5 ft.

Vineyard Road FRS experiences flow in the auxiliary spillway for the 500-year, 24-hour existing conditions storm event at a depth of 0.5 ft in the south spillway. The 500-year, 24-hour event is the only existing conditions auxiliary flow for Vineyard Road FRS. The future conditions land use 100-year, 24-hour event for Vineyard Road results in a flow depth of 0.6 ft in the south auxiliary spillway. The future conditions land use 500-year, 24-hour event results in a flow depth of 1.8 ft in the south auxiliary spillway and 1.2 ft in the north auxiliary spillway.

Rittenhouse FRS experiences flow in the auxiliary spillway for the 500-year, 24-hour existing conditions storm event at a depth of 1.0 ft. The 500-year, 24-hour event is the only existing conditions auxiliary flow for Rittenhouse FRS. The future conditions land use 100-year, 24-hour event for Rittenhouse FRS results in a flow depth of 0.6 ft in the auxiliary spillway. The future conditions 500-year, 24-hour event results in a flow depth of 1.9 ft in the auxiliary spillway. The future conditions land use “with retention” results in no flow for the 100-year 6-hour or 100-year 24-hour events.

For all three FRSs, the future conditions multi-frequency peak flow rates, peak storage volumes and peak stages increase relative to existing conditions. The percent increase is highest during more frequent return intervals (i.e. the 2-year storm event) and lowest during less frequent return intervals (i.e. the 500-year event). Both the 100-year 6-hour and 100-year 24-hour future conditions with retention models for all three FRSs result in a decrease in peak storage volume and peak stage and no outflow in the auxiliary spillways.

The 6-hour reduced PMP overtops the Powerline FRS crest by 0.6 ft in both the existing and future conditions. The structure is not overtopped in the existing or future conditions 24- and 72-hour reduced PMP events.

The existing conditions 6- and 72-hour reduced PMP events overtop the Vineyard Road FRS crest by 1.2 and 0.8 ft, respectively. The future conditions 6-, 24- and 72-hour reduced PMP events all overtop the Vineyard Road FRS crest by 1.3, 0.4 and 0.7 ft, respectively. Vineyard Road FRS is not overtopped in the 24-hour existing conditions reduced PMP event.

Rittenhouse FRS is overtopped in all existing and future conditions reduced PMP events. The existing conditions 6-, 24- and 72-hour reduced PMP events overtop the Rittenhouse FRS crest by 1.0, 0.1 and 0.3 ft, respectively. The future conditions 6-, 24- and 72-hour reduced PMP events overtop the Rittenhouse FRS crest by 1.0, 0.1 and 0.2 ft, respectively.

2.6 Dynamic Reservoir Routing Results

HEC-1 existing conditions inflow hydrographs developed for the 100-year, 6-hour and 100-year, 24-hour storms and the 6-, 24- and 72-hour reduced PMP storms were used to update the dynamic reservoir routing FLO-2D models prepared as part of the “DDA Inundation and Sedimentation” (ASLD, 2007). The FLO-2D models were used to generate auxiliary spillway outflow hydrographs and freeboard estimates for each FRS.

2.7 Principal Spillway Hydrograph, Stability Design Hydrograph and Freeboard Hydrograph

Kimley-Horn prepared the “Principal Spillway Hydrograph, Stability Design Hydrograph and Freeboard Hydrograph Technical Memorandum” (PSH, SDH and FBH Technical Memorandum, Kimley-Horn 2010) to document the future land use conditions principal spillway hydrograph (PSH) analysis and the existing and future conditions stability and integrity analysis for the existing PVR auxiliary spillways.

Kimley-Horn used the PVR FRSs Existing Conditions PSH Analysis single basin models as the basis for the future land use PSH analysis. The NRCS SITES Analysis Computer Program was used to complete the analysis. Future conditions land use was taken from the "Existing and Future Hydrology and Hydraulics Update" (Kimley-Horn, 2010). The time for PSH drawdown increased for Powerline and Vineyard Road FRSs during future conditions. The PSH drawdown did not change for Rittenhouse FRS because the composite CN value did not change for future land use conditions. None of the FRSs experience auxiliary spillway flows during the 100-year, 10-day event for existing or future land use conditions.

An existing and future conditions stability and integrity analysis for the existing PVR auxiliary spillways was completed. The 6-hour reduced PMP storm event was determined to be the critical storm duration for each FRS in the "Final PMP Tech Memo" (Kimley-Horn, 2010) and was used to develop the SDH and FHB.

Precipitation depths used for the FBH and SDH equation were taken from the "Existing and Future Conditions Hydrology and Hydraulics Update Technical Report" (Kimley-Horn, 2010). The reduced PMP value was used for the SDH and FBH. SDH and FHB were calculated using the 6-hour HMR-49 distribution.

Precipitation depths were input in HEC-1 models from the "Existing and Future Conditions Hydrology and Hydraulics Update Technical Report" (Kimley-Horn, 2010h) to determine the flood hydrographs at each structure. HEC-1 inflow hydrographs were imported into FLO-2D and dynamically routed through the reservoir to obtain the spillway hydrographs. The hydrographs were then input into SITES to evaluate the stability and integrity of each auxiliary spillway.

The allowable stress for each spillway was calculated using a spreadsheet developed by the NRCS that follows Agricultural Handbook (AH) 667 and TR-60 methodology. The soil effective stress was obtained from the SITES output file for each spillway and compared to the calculated allowable stress. The soil is stable for Vineyard Road and Rittenhouse auxiliary spillways under existing conditions with the SITES soil effective stress being less than the calculated allowable stress. The soil is erodible for Powerline auxiliary spillway under existing conditions where the effective stress is greater than the calculated allowable stress. Under future conditions, the soil is stable for the Vineyard Road north and Rittenhouse auxiliary spillways. The soil is erodible for the Powerline and Vineyard Road south auxiliary spillways.

An integrity analysis was completed for each auxiliary spillway using the SITES model. There are four spillways, one at Powerline, two at Vineyard Road, and one at Rittenhouse. Soil borings were taken at each spillway and documented in detail in the "Final Geotechnical Summary and Analysis Report" (AMEC, 2010).

Representative soil parameters were selected from the available laboratory results for each SITES material. Spillway profiles used in the analyses are a composite of the as-built spillway profiles and the existing topography spillway profiles prepared by AMEC (AMEC, 2010). The profiles were simplified to include a 50-ft long control crest section followed by a constructed exit channel at a constant slope. A non-constructed spillway section was extended beyond the constructed spillway section to the valley floor in each spillway profile. All four auxiliary spillways breach under both existing and future conditions. The time to breach ranges from 7.0 to 8.5 hours for the PVR FRSs.

2.8 Downstream Inundation Analysis

The "Downstream Inundation Hydrology and Mapping Technical Memorandum" (JEF, 2010) provides inundation data downstream of the PVR structures to support the economic analysis for subsequent alternatives evaluation and selection.

Both the "with dams" and "without dams" 2-, 5-, 10-, 25-, 50-, 100-year 24-hour, and 100-year 6-hour storm events were dynamically routed using FLO-2D through the watershed downstream of the PVR FRSs. Inflow hydrographs at the PVR FRSs used in the FLO-2D model were obtained from the multi-frequency analysis conducted as part of the "Existing and Future Conditions Hydrology and Hydraulics Update" (Kimley-Horn, 2010). A single, areal reduced point precipitation depth was applied to the downstream watershed to generate runoff within FLO-2D. The results show substantially shallower and moderate flooding across the downstream watershed for the "without dams" scenario than the "with dams" scenario.

2.9 Sediment Yield Analysis Update

The Flood Control District conducted an updated projected sediment yield analyses for the existing PVR structures for the purposes of the PVR FRS Rehabilitation or Replacement project (Flood Control District December, 2010) for future hydrologic land use conditions.

The methodology used by the District to estimate the sediment yield can be found in the District's River Mechanics Manual for the Drainage Design Management System for Windows (DDMSW version 4.6.0). The District used the DDMWS version 4.6.0 (with river mechanics) to determine total sediment yield. The total sediment yield consists of wash load and total bed material load. The *wash load* is calculated with the MUSLE method, and the *total bed material load* is calculated with the Zeller-Fullerton equation (Zeller and Fullerton, 1983), which is based on the assumption that the reach is at an equilibrium condition.

The District's results are summarized in the following table.

Summary of Sediment Yield Analysis Update

FRS	Sediment Yield [ac-ft/mi^2/yr]	Contributing Area[1] [mi^2]	25-Year Sediment Volume [ac-ft]	100-Year Sediment Volume [ac-ft]
Powerline	0.238	34	203	810
Vineyard Road	0.272	53	361	1442
Rittenhouse	0.151	42	160	641

The NRCS criteria for sediment storage for dams may be found in *Technical Release 60, Earth Dams and Reservoirs* (*TR-60*). TR-60 refers to the NRCS publication *National Engineering Handbook (NEH) No 3 – Sedimentation (NEH-3)* for criteria and general guidelines for estimating sediment yield. The NRCS *National Watershed Program Manual (NWM)* (Dec, 2009) provides guidelines for the rehabilitation of existing dams and sediment storage volume requirements. On page 78, Section 505.35, B, paragraph iii states that for the rehabilitation of an existing dam: “Sediment storage life will be for the longest reasonable period practical (100 years maximum) but in no case will the evaluation life be less than 50 years”.

2.10 Freeboard

Freeboard was estimated as the sum of wave runup plus wave setup in accordance with procedures described in Freeboard Criteria and Guidelines for Computing Freeboard Allowances for Storage Dams, ACER Technical Memorandum No. 2 by the United States Bureau of Reclamation (USBR), revised in 1981 (ACER-TM2). Wave runup is the movement of water up a structure on the breaking of a wave and the amount of runup is the vertical height above still water level. Wave setup is the vertical rise in the still water on the leeward side of a body of water caused by the wind stresses on the surface of the water. The two are summed for wave action.

The existing embankments for the PVR structures have been in place since 1968-1969 and are assumed fully settled. For the purposes of this planning level study, it is assumed that additional freeboard to compensate for future settlement is not required. Freeboard also accounts for anticipated future land subsidence at each structure.

2.11 Level II Hydrology and Hydraulics Technical Memorandum

The purpose of this Hydrology and Hydraulics Technical Memorandum was to document the hydrologic and hydraulic approach, methodology and results for evaluation of the Level II planning alternatives for the PVR project. This hydrologic and hydraulic study was used to conduct preliminary evaluations of the identified alternatives.

The scope of this study was to conduct updated hydrologic/hydraulic analyses to evaluate future project alternative conditions for the PVR Level II analysis planning alternatives. Previous hydrologic and hydraulics studies conducted by Kimley-Horn for existing PVR conditions are used as a baseline and updated for project alternatives. The tasks performed in developing this memorandum are listed below.

- Update previously prepared HEC-1 hydrologic models for five planning alternatives.
- Conduct FLO-2D modeling for the five planning alternatives. Model alternatives including dam rehabilitation for the inflow design flood and alternatives including basins and channels for the 100-year, 24-hour storm.

2.12 Final Level III Alternatives Summary Report

This report documents the evaluation of Level III alternatives for the PVR structures and presents the results of the analysis of those alternatives. The analysis includes hydrology and hydraulics for each of the Level III alternatives, geotechnical and geohazard evaluation, identification of existing and planned utility corridors and transportation infrastructure, development of conceptual landscape themes and recreational opportunities, and development of preliminary construction cost estimates.

The hydrology and hydraulics evaluations of two planning alternatives were conducted as part of the Level III study. Updated rating curves for the auxiliary spillways and for Vineyard Road and Rittenhouse FRSs were prepared and documented in Appendix C of the report. These updated rating curves were input into FLO-2D models to evaluate the operational response of the alternatives.

3. ECONOMICS

This section provides an abbreviated summary of the economic evaluation conducted in support of the Supplemental Watershed Plan and Environmental Assessment for the PVR project. The reader is referred to the full economic evaluation technical memorandum for further details and information.

The PVR economic evaluation is documented in the following report:

- Powerline, Vineyard Road and Rittenhouse Flood Retarding Structures Supplemental Watershed Plan/Environmental Assessment Economics Evaluation Technical Memorandum. (Gannett Fleming Inc. January, 2013)

3.1 Economics Evaluation Technical Memorandum Summary

The economics evaluation was prepared in support of the Powerline, Vineyard Road and Rittenhouse Flood Retarding Structure Supplemental Watershed Plan and Environmental Assessments (Plan/EAs). The memorandum describes the methodology and summarizes the results of the benefit-cost analysis. The analysis was conducted on the following two alternatives:

- Alternative 8A: Replace Powerline FRS, Rehabilitate Vineyard Road FRS, and convert Rittenhouse FRS to a levee,
- No Federal Action Alternative (Future Without Project)

The benefit-cost analysis follows the procedures outlined in the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G)*, the *Natural Resource Economics Handbook Part 611 – Water Resources* and the *National Watershed Manual* (Dec 2009). All values in the analysis are in 2012 prices and all annual values have been discounted using the FY2012 federal discount rate for water resources projects of 3.750 percent. Economic values were derived based on each of the three dams as a single analysis unit.

The study area for the economics evaluation encompasses approximately 54.5 square miles immediately downstream of the Powerline, Vineyard and Rittenhouse dams in Maricopa and Pinal Counties, AZ. The study area for the project was defined as the limits of the 100-year floodplain downstream of the three dams without the dams in place. This area encompassed the farthest extent of flooding for the combination of alternatives and storm events examined within the scope of the project. Study area land uses include agriculture, residential, commercial, industrial, institutional, and infrastructure.

3.1.1 Study Area Inventory

To identify study area land uses, GIS tax parcel data was obtained from the Maricopa and Pinal Counties Tax Assessor's Offices. A database of tax parcels within the study area limits was created using ArcGIS. The parcels were then divided using the Assessor's Use Code descriptions into the following categories:

- Residential – existing residential properties
- Residential(new) – residential properties under construction, or imminently to be constructed
- Commercial/Industrial – existing commercial and industrial businesses, Phoenix-Mesa Gateway Airport

- Institutional – K-12 schools, churches, college campuses, federal, county and municipal properties
- Agricultural – active agricultural land
- Agricultural(structures) – parcels including both active agricultural land and agricultural buildings
- Infrastructure – roads, irrigation districts, utilities' right-of-way
- Vacant – vacant land (regardless of zoning designation)

The accuracy of the parcels database and Use Codes was verified through a fieldview and examination of aerial photography.

Population-at-Risk (PAR)

The population benefiting from the dams consists of the population that would be inundated by an uncontrolled breach of the dam. Dambreak scenarios for each FRS were previously modeled for the "Powerline, Vineyard and Rittenhouse Flood Retarding Structures Emergency Action Plan" (FCD 2006).

The estimated population within the dambreak floodplain limits, based on the structures inventory, were estimated and provided in the memorandum. Where the dambreak floodplain limits fell outside of the study area, the estimated number of residential structures was extrapolated based on a percent increase or decrease in the study area population (i.e., the Rittenhouse FRS dambreak limits were 14% larger than the overall study area, so the population of the study area was multiplied by 1.14 to estimate the dambreak population). This extrapolation was verified with aerial mapping denoting approximate population density. Household size was estimated using 2010 U.S. Census Bureau demographic data on average household size for Maricopa and Pinal Counties. The estimate (2.73 persons) is an average of the two counties (2.67 and 2.78 persons, respectively).

For commercial/industrial and institutional structures, population estimates were based on daytime occupancy. Commercial/industrial and institutional structures estimates were based on the structures inventory. The Phoenix-Mesa Gateway Airport falls within the dambreak floodplain for all three dams, and so was included in each population at risk estimate. The average occupancy at the airport was estimated using data from the Phoenix-Mesa Gateway Airport Authority's report, *Economic Benefit Analysis, FY 2010*. Average occupancy at Arizona State University Polytechnic Campus was estimated to be approximately 1/2 of the annual enrollment of 9,700 students. Average occupancy at Mesa Community College, a commuter campus, was estimated to be approximately 1/4 of the annual enrollment of 27,000 students.

For the portion of the dambreak area outside the project study area, 2010 U.S. Geological Survey GIS data was used to identify additional schools. It was outside the scope of the analysis to identify additional commercial/industrial and other institutional structures individually for the portion of the dambreak area outside the project study area. Instead, the number of these structures was extrapolated based on study area totals.

The PAR estimated in the technical memorandum represents a conservative approach and estimate.

3.2 Hydraulic Model

Hydraulic modeling of the downstream inundation area with and without the PVR structures was prepared using the FLO-2D flood routing model, version 2009.06. A 500-foot by 500-foot grid was developed for the computational domain area and ground elevations were obtained from the District's 10-foot topography with supplemental 2-foot contour data sets from the District.

Further details regarding the hydrologic and hydraulic modeling conducted for the project can be found in the following references:

- "PVR Existing and Future Conditions Hydrology and Hydraulics Update Technical Report", Kimley-Horn and Associates, Inc., November 2010.
- "PVR Downstream Inundation Study", JE Fuller, Inc., November 2010.

Appendix A of the technical memorandum for floodplain delineation mapping shows the inundation limits for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year storm events for each scenario.

3.3 Benefits: Preferred Alternative and No Federal Action Alternative

Benefits were estimated for the following two alternatives:

- Alternative 8A: Replace Powerline FRS, Rehabilitate Vineyard Road FRS, and convert Rittenhouse FRS to a levee (Preferred Alternative)
- No Federal Action Alternative (Future Without Project)

The No Federal Action/Future Without Project represents the sponsor's most likely course of action in the absence of federal funding. For this study, the "No Federal Action/Future Without Project Alternative" was defined as the following:

> The District would continue to operate and maintain the Powerline, Vineyard Road, and Rittenhouse Flood Retarding Structures under existing conditions until the end of the structures' design lives. The structures would continue to have identified safety deficiencies and would not meet current NRCS and ADWR performance standards. Under this alternative, the structures would continue to provide flood protection until and if there is a sudden breach event. This condition is unacceptable to the District and NRCS.
>
> The District has indicated that without federal financial assistance, sufficient funds are not available to rehabilitate or replace the structures in a timely manner. The District recognizes, however, that there remains a need to address the existing safety deficiencies. Therefore, the District would eventually rehabilitate or replace the dams one at a time as non-federal funds become available. The District estimates that rehabilitation/replacement using local funds would occur (after approval of the Supplemental Watershed Plan)for the first structure in year 20, the second structure in year 25, and the third structure in year 30.
>
> This alternative is not acceptable to the Sponsors and local community as a viable solution, since the structures would continue to have safety and performance deficiencies and continue to pose a significant risk of catastrophic failure until such time of the structures' eventual rehabilitation, replacement or removal from service.

Because both of the alternatives, including the No Federal Action/Future Without Project, continue to provide flood protection throughout the project life, the benefits are same for each alternative.

Benefits for the project were based upon the reduction of flood damages. Flood damages under both a With Dams and Without Dams scenario were estimated. The difference in flood damages between the two scenarios can be considered a benefit of retaining flood protection.

To analyze each dam as a single analysis unit, the downstream study area was reviewed by project hydrologists to provide an approximate demarcation of flooding impacts attributable to each dam. The study area was divided into four regions: one region for the floodplain of each dam, and a fourth region where Vineyard FRS and Rittenhouse FRS have overlapping floodplains (see Figure 1). Benefits for the overlapping floodplain were allocated by each FRS's percent control, measured by a comparison of total acre feet retained behind each structure. It was determined that the storage capacity behind the two dams was nearly identical and benefits were allocated accordingly at 50% for each dam.

3.4 Costs: Preferred Alternative and No Federal Action Alternative

Cost estimates for each alternative were developed by project engineers in conjunction with NRCS and the Flood Control District of Maricopa County.

Average annual equivalent costs for each alternative were prepared. Costs were brought to present value using the 2012 federal water projects discount rate of 3.750 percent, amortized over the 103-year project analysis period, and described in annual terms for comparison to project benefits. The net present value calculation assumed that flood protection would remain in place for all alternatives throughout the project life. Under the No Federal Action Alternative, Powerline FRS was assumed to be reconstructed in project year 20, with Vineyard and Rittenhouse reconstructed in years 25 and 30, respectively. For the build alternatives, construction was assumed to occur in three years. Project administration, permitting and engineering costs for all alternatives were assumed to occur one year prior to construction.

Annual operation and maintenance costs (O&M)for the Preferred Alternative were estimated by project engineers. For the No Federal Action alternative, O&M costs were assumed to be approximately $512,000 per year until the dam is rehabilitated or replaced. After rehabilitation/replacement, O&M costs were assumed to be equivalent to the Preferred Alternative O&M estimates.

3.4.1 Benefit-Cost Ratio

For water and related land resources implementation studies, standards and procedures have been established in formulating alternative plans. These standards and procedures are found in the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G). According to P&G, an alternative that reasonably maximizes net national economic development benefits is to be formulated. This alternative is to be identified as the National Economic Development (NED) plan. A comparison of the alternatives was provided in the technical memorandum.

The Preferred Alternative (8A) is the plan that reasonably maximizes the net benefits and is therefore identified as the NED plan. It can be noted that for all three dams, the net benefits shown in the tables are higher for the No Federal Action alternative than for the Preferred Alternative. This occurs because the No Federal Action alternative assumes that the dams would not be rehabilitated or replaced until 20-30 years into the future. In the interim, the dams would continue to provide flood protection benefits. Therefore, the costs of No Federal Action are lower, while the benefits remain the same. However, the No Federal Action alternative does not meet the purpose and need of the project because it does not remove the safety risk presented by the aging dams for two decades into the future. This is judged to be an unacceptable risk to human life and property by NRCS and the sponsor. For dam rehabilitation projects with risk to human life, NRCS policy defines the NED Alternative as the "federally assisted alternative with the greatest net economic benefits." Therefore, the Preferred Alternative (8A) has been identified as the NED alternative.

The Preferred Alternative results in a benefit to cost ratio of 0.1 to 1.0 for Powerline FRS, a ratio of 0.1 to 1.0 for Vineyard FRS, and a ratio of 0.1 to 1.0 for Rittenhouse FRS. The benefit to cost ratio for the dams are less than 1.0, but still provides the greatest net benefits (or fewest negative net benefits) of any alternative that meets the purpose and need of the project.

3.4.2 Risks and Uncertainty

The areas of risk and uncertainty associated with the economic analysis include uncertainty associated with the hydrologic and hydraulic modeling, simplifying assumptions used to run the URB-1 model, and uncertainty related to the future changes in cost estimates as engineering design progresses.

Hydrologic modeling over a wide swath of floodplain introduces an element of uncertainty in estimating attenuation and resulting peak flows. The hydraulics analysis relies partially on engineering judgment and experience to designate ineffective/effective flow areas over the wide and shallow floodplain of the study area.

Several simplifying assumptions were used to create input for the URB-1 model. Parcel elevations were determined using topographic contour data. Residential parcels were proportionally assigned as either a single story or two-story residence based on the fieldview determination that these two housing types were interspersed throughout the study area. Content values for parcels were estimated based on a percentage of their tax assessed structure value. The structure and contents value for some parcels were estimated using Marshall Valuation Service data. While these assumptions represented the best methodology available within the scope of the analysis, the model results may slightly overestimate or underestimate damages due to the simplifying assumptions used to create the input data.

4. GEOTECHNICAL

This section provides an abbreviated summary of the geotechnical investigations and analyses for the PVR project. The reader is referred to the full geotechnical reports for further details and information in regards to the PVR structures.

The PVR geotechnical studies are documented in the following reports:

- "Powerline, Vineyard Road and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project Final Geotechnical Summary and Analysis Report". (AMEC August, 2010)
- "Powerline, Vineyard Road and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project Final Filter Alternatives Memorandum". (AMEC May, 2012)

4.1 Final Geotechnical Summary and Analysis Report

The purpose of the "Final Geotechnical Summary and Analysis Report" was to provide an overview of the existing geological and geotechnical conditions at the three dams. The results, findings and conclusion of the report were used by the project team in its development and evaluation of dam rehabilitation and/or replacement alternatives.

The geotechnical summary report presents summaries of the original geotechnical investigations, design and construction of the three dams and the Powerline Floodway; the subsequent geological and geotechnical investigations performed to evaluate cracking of the dams; and the methods of repairing the structures conducted previously. The history and causes of the cracking and the modifications that were made to safeguard against failure of the structures were presented and discussed, as was the current understanding of the geotechnical conditions of the embankments and foundation soils. This report also presents a description of the geological setting of the study area, an overview of the condition of the principal outlets and other penetrations in the embankments, and a characterization of the subsurface conditions at the auxiliary (emergency) spillways.

4.1.1 Previous Investigations

The Geotechnical Summary Report reviewed and provided summaries of eighteen (18) previous geotechnical related investigations for the PVR structures. This "Existing Conditions Summary Report" does not provide a synopsis of this summary provided in the Geotechnical Summary Report. The reader is referred to the Geotechnical Summary Report.

4.1.2 Planning Geotechnical Investigation

Field investigations conducted as part of the PVR project were based on the District's identification of a need to rehabilitate and/or replace the Powerline, Vineyard Road and Rittenhouse FRS dams. Locations of borings, test pits, test trenches and seismic refraction survey lines performed during previous investigations were plotted on site plans of the three structures. Based on a review of these data, 41 additional exploration borings and four additional seismic refraction surveys were conducted to fill in data gaps and further characterize geological and geotechnical conditions at and adjacent to the dams and the Powerline Diversion Channel.

4.1.3 Regional Geologic Setting

The PVR study area is near the junction of the Mexican Highland and Sonoran Desert sections of the Basin and Range physiographic province, just southwest of the boundary between the Basin and Range and Transition Zone physiographic provinces. The boundary between these two provinces is marked by the western edge of the Superstition and Goldfield mountains, which rise abruptly above the valley floor. These mountain ranges also mark the eastern margin of the down-dropped Phoenix Basin, which underlies much of the Phoenix metropolitan area and extends westward to the Sierra Estrella and White Tank Mountains. The Phoenix Basin formed between approximately 8 and 15 million years ago after cessation of the volcanic activity that formed the bulk of the Goldfield and Superstition mountains.

The Phoenix Basin is subdivided into several sub-basins. The study area is within the Mesa-Chandler sub-basin. On the west, this sub-basin is partially separated from the central Phoenix Basin by the bedrock highs of the Tempe Butte area. The Mesa-Chandler sub-basin is bounded by the Goldfield and Superstition mountains on the north and northeast, by Mineral Mountain on the east, and by the Santan Mountains on the southwest.

4.1.4 Local Geomorphic Setting

The Powerline FRS is underlain by deposits typical of a basin floor and identified as fine-grained distal alluvial fan/alluvial plain and terrace deposits with little soil development. These basin floor deposits are incised by younger Holocene piedmont and intramontane deposits identified as channel deposits of ephemeral streams consisting of stratified sand, silt, pebbles, cobbles and boulders with little or no soil development.

The northern and central portions of the Vineyard Road FRS are underlain by an upper horizon of fine-grained alluvial fan and terrace deposits consisting of sand, silt and fine gravel. The southern portion of the Vineyard Road FRS and the Rittenhouse FRS are underlain by an upper horizon of piedmont and intramontane, low terrace and alluvial fan deposits consisting of poorly sorted silt, sand, pebbles, cobbles and boulders with weak soil development. These deposits have minimal soil development and are all incised by ephemeral streams containing channel deposits of stratified sand, silt, pebbles, cobbles and boulders with little or no soil development. These near-surface deposits, which are similar to the Holocene soils described throughout this report, are underlain by moderately to strongly cemented, predominantly fine-grained Late Pleistocene deposits.

4.1.5 Local Geologic Setting

Surface Geology

The Powerline FRS is underlain by four geologic units: Holocene Alluvial Channels Holocene Alluvial Surface; Undifferentiated Holocene Alluvium and Holocene to Late Pleistocene Alluvium.

The Vineyard Road FRS is underlain by five geologic units: Holocene Alluvial Channels; Holocene Alluvial Surface; Undifferentiated Holocene Alluvium; Holocene to Late Pleistocene Alluvium; and Late Pleistocene Alluvium. The geologic units are the same units described above for the Powerline FRS, with the exception of Late Pleistocene Alluvium, which occurs at the far southern limit of the structure.

The Rittenhouse FRS is underlain by four geologic units: Holocene Alluvial Channels; Holocene Alluvial Surface; Late Pleistocene Alluvium; and Middle to Late Pleistocene Alluvium. The first three geologic units have been described above for the Powerline and Vineyard Road FRS. The fourth unit Middle to Late Pleistocene Alluvium is located beneath the southernmost portion of the FRS.

Near-Surface Geologic Profile

The FRSs are underlain by shallow low-density soils that were deposited at the distal end of coalescing alluvial fans during the Holocene era (the last approximately 11,000 years). The soils were deposited during semiarid climatic conditions similar to present-day conditions, and the depositional processes included sediment transport in channels and periods of flooding which resulted in avulsion of braided channels, debris flows and mudflows. These processes resulted in a high degree of stratification and variation in soils types. The Holocene soils typically vary from 10 to 20 feet in thickness and are dominated by sandy clay and clayey sand with subordinate amounts of silty sand, sandy silt and sandy gravel.

The Holocene soils are uncemented or exhibit discontinuous Stage I calcareous (lime) cementation, and are predominantly moderately firm to firm with some soft and very firm zones. The Holocene soils have a high potential for collapse settlement, and typically experience from 2 to 6 percent of vertical strain upon wetting under their own weight or low superimposed loads.

The Holocene soils are underlain by Late Pleistocene alluvium primarily consisting of silty sand, clayey sand, gravelly sand and sandy clay. These soils typically possess Stage II or III calcareous cementation, are characterized as being very firm to hard with some firm zones, and are essentially incompressible from the viewpoint of contributing to settlement of low embankments. Based on a review of geotechnical investigations conducted in the study area, it appears that the thickness of the Holocene soils varies considerably over short distances, suggesting that the contact between the Holocene and Pleistocene soils is a buried erosional surface with considerable past relief.

The depth of the Holocene/Pleistocene contact below the original ground surface, the depths of the cutoff trenches along the upstream side of the dams, and the depths of the central drains within the embankments are important considerations when considering several of the potential failure modes for the structures. The potential presence of poor foundation conditions beneath the dams and how these conditions relate to potential failure modes are discussed in Section 5.5 of this section.

4.1.5.1 SOIL PROFILES UNDERLYING STRUCTURES BASED ON ALL GEOTECHNICAL INVESTIGATIONS

The following descriptions of the geotechnical profiles at the structures are based on a review of published literature and available boring and test pit logs from previous geotechnical investigations and the results of subsurface investigations completed as part of this study.

Powerline FRS

The geotechnical profile underlying the Powerline FRS is best described as a three-layer profile. Unit P1 consists of Holocene soils with little to no cementation; Unit P2 is composed of Holocene to Late Pleistocene soils with little to no cementation; and Unit P3 soils are Pleistocene in age with Stage II to III cementation. The units are described below.

Vineyard Road FRS

The geotechnical profile at the Vineyard Road FRS is similar to the profile at the Powerline FRS, but it is best described as a two-layer profile rather than a three-layer profile. Unit V1 consists of Holocene soils with little to no cementation, and Unit V2 is composed of cemented Pleistocene soils that are similar to Unit P3 of the Powerline FRS. The number of seismic lines completed along the Vineyard Road FRS is not sufficient to characterize the subsurface seismic velocity profile in the same detail as at the Powerline FRS.

Rittenhouse FRS

The geotechnical profile underlying the Rittenhouse FRS varies from north to south. Soils beneath the northern portion of the dam (Stations 115+00 to 210+00) are similar to the soils underlying the Vineyard Road FRS. Most of these soils classify as silty to clayey sand or silty clay with some sand. These soils are best described by a two-layer profile similar to the profile beneath the Vineyard Road FRS. Unit R1N consists of Holocene soils with little to no cementation and Unit R2N is comprised of Pleistocene soils.

4.1.6 Discussions

This section contains discussions on the following topics:

- Failure modes (with an emphasis on the impacts of the presence of Holocene soils beneath the dams),
- Data gaps and recommendations for additional investigations

4.1.6.1 FAILURE MODES (WITH AN EMPHASIS ON THE IMPACTS OF THE PRESENCE OF HOLOCENE SOILS BENEATH THE DAMS

Site Specific Failure Modes.

Failure mode and consequence analyses (FMCA) were performed for each of the three FRS in 2001 and 2002. The objective of the FMCA was to gain an understanding of the most significant site-specific potential failure modes for each of the structures and the consequences that could result from these potential failures.

Several of the potential failure modes result from, or are exacerbated by, the presence of Holocene soils (poor foundation conditions) beneath the structures or inadequate penetration of the upstream cutoff trench or central filter into Late Pleistocene soils.

The most significant of these potential failure modes is seepage erosion or piping resulting from flow through Holocene soils beneath the dam embankments or along the dam/foundation contact. There are three potential pathways associated with this failure mode. The pathways are described as follows:

- Path A – This failure mode is initiated by flow into transverse and longitudinal cracks that do not extend through the central filter, but do extend into foundation materials underlying the central filter and are in contact with Holocene soils.
- Path B – This failure mode is initiated by flow from the impoundment into differential settlement cracks that extend below the central filter and are in contact with Holocene soils.

- Path C – This failure mode is initiated by flow through remnant upstream borrow areas that contain considerable amounts of gravel and provide potential seepage pathways along buried gravel-rich channels into Holocene soils that underlie the embankments.

Paths A and B were identified as Category I potential failure modes for both the Vineyard Road and Rittenhouse FRS, and Path C was identified as a Category II failure mode for both the Vineyard Road and Rittenhouse FRS. Path A was identified as a Category III failure mode for the Powerline FRS.

The presence of Holocene soils beneath the embankments also was identified as a contributing factor to a potential failure mode in which impounded water flows into a transverse crack and initiates seepage erosion leading to a breach of the embankment.

Two modes of failure were identified:

- Mode A – This failure mode is initiated by flow through a large (wide) transverse crack that extends across the central filter.
- Mode B – This failure mode is initiated by flow through multiple upstream longitudinal and transverse cracks to a flaw(s) in the central filter that causes seepage erosion of the central filter materials and loss of these materials through a downstream transverse crack. In general, this failure mode requires that cracks in the upstream and downstream sides of the embankment and the flaw(s) in the central filter be aligned in a near linear arrangement.

Failure Modes A and B were identified as Category I failure modes for all three structures.

The presence of Holocene soils beneath the embankments could also contribute to an additional potential failure mode: seepage-erosion due to development of an earth fissure through or beneath a structure. An earth fissure crossing a dam could create a continuous crack through the underlying foundation soils and/or embankment. If an undetected earth fissure were present during a major flood event, there would be a high risk of rapid seepage erosion through highly erodible Holocene soils located just below the embankment. This condition was identified as a Category I potential failure mode for the Powerline and Vineyard Road FRS and as a Category II potential failure mode for the Rittenhouse FRS.

Descriptions of Foundation Excavations and Central Filters

The three dams were constructed almost entirely using Holocene soils derived from upstream borrow areas, including the upstream cutoff trench, and from excavation of foundation soils below the footprint of the embankment. Excavation of the upstream cutoff trenches and excavation of the dam foundations resulted in the presence of “shelves” that generally extend 2 to 4 feet below original natural grades. The shelves beneath the Vineyard Road and Rittenhouse FRS extend from the upstream cutoff trench to a minimum of 22 feet downstream of the dam centerline. The shelf beneath the Powerline FRS extends from the upstream cutoff trench to a minimum of 10 feet downstream of the dam centerline.

Profiles of the upstream trench excavations and profiles of the shelves at the dam centerlines are presented on the as-built plans of the FRS, with the exception of the shelf at the Rittenhouse FRS. These profiles are discussed in the report sections that follow. In general, the upstream cutoff trench was designed to extend through the softer, collapse-prone Holocene soils and into the cemented Late Pleistocene soils along the entire length of the dam alignment.

Central filters were installed along the centerline of all three dams. The central filter installed in the Powerline FRS extends along the entire length of the embankment (from Stations 17+83 to 150+70). The filter has an average depth of 18 feet and a maximum depth of 42 feet. The depth of the filter was established by the NRCS on the basis of its 1986 crack location investigation. The central filter extends through the embankment and into native soils along much, but not all of the dam. There are several areas where the filter does not extend through the entire embankment.

The central filter in the Vineyard Road FRS extends along the entire length of the embankment (from Stations 85+00 to 360+00). As indicated on as-built plans of the filter, the central filter extends to depths of between 19 and 21 feet below the crest of the dam along most of its alignment, corresponding to depths of between 2.5 to 4.5 feet below the original ground surface. There are several areas where the filter does not extend through the entire embankment.

The central filter in the Rittenhouse FRS extends from Stations 80+00 to 210+00, but it was not installed in the southern 5,000 feet of the embankment between Stations 30+00 and 80+00. The filter was designed to extend 12 feet below the crest of the dam, except where deeper cracks were observed in the trench by an onsite NRCS representative. In areas where cracks extended beyond a depth of 12 feet, the filter was deepened until there was no further evidence of the presence of the crack. The central filter has an average depth of 12.8 feet between Stations 80+00 and 109+72 and an average depth of 15.8 feet between Stations 109+72 and 200+00. The filter varies in depth from 14.6 to 6.9 feet between Stations 200+00 and 210+00. Forty outlet drains were constructed between Stations 80+00 and 200+00 of the Rittenhouse FRS at approximately 1,000-foot intervals along the dam or as directed by the Engineer. The outlet drains slope toward the downstream toe of the dam and are designed to provide positive drainage from the central filter.

The central filters in the Powerline and Vineyard Road FRS are 3 feet wide, whereas the central filter in the Rittenhouse FRS has a nominal width of 2.6 feet. Unlike the central filters in the Powerline and Vineyard Road FRS, the filter in the Rittenhouse FRS is not continuous over the entire length of the dam nor was it designed to extend through the entire embankment into the underlying soils. Outlet drains were installed in the Rittenhouse FRS, but not the Powerline or Vineyard Road FRS.

Collapsing Foundation Soils

The Holocene soils beneath the dams have characteristics that are typical of collapsible soils, including depositional environment, low blow counts, low dry density (indicative of an open soil structure) and weak cementation. Some of the Late Pleistocene soils that underlie the Holocene soils have similar characteristics. The collapse potential of these soils was tested in the laboratory by performing one-dimensional consolidation tests using relatively undisturbed samples obtained during the current field investigation. The collapse potential of the samples tested ranged from 0.0 to 8.7 percent with an average collapse potential of 1.5 percent. The dry density of the 74 samples ranged from 88 to 124.2 pcf and averaged 104.5 pcf.

The formation of cracks due to collapsing foundation soils is the result of differential collapse that occurs when soils that underlie the structures are not equally wetted. The amount of collapse also depends on the thickness of the collapsing soil layer. Water has been impounded behind all three dams, most notably during October 1972. Impoundment of this water likely resulted in partial collapse of the Holocene soils, and to a lesser extent the Late Pleistocene soils, underlying the upstream section of the embankments. The rate of infiltration into the Holocene soils is estimated to range from 0.5 to 3 feet per day (Hansen and others 1989). The flood event of 1972 likely resulted in the wetting of Holocene soils beneath the upstream slope of the embankments to a distance of 5 to 30 feet downstream from the upstream toe of the embankments. It is probable that this wetting resulted in differential collapse of a variable thickness of soils, resulting in longitudinal cracks developing at various elevations in the upstream slope of the embankments.

4.1.6.2 DATA GAPS AND RECOMMENDATIONS FOR ADDITIONAL INVESTIGATIONS

The following should be considered as part of planning and/or final design:

- No documentation of stability analysis is being performed for any of the structures, neither during the original design of the structures nor during subsequent studies. Depending upon the alternatives recommended a stability analysis should be considered for the structures.
- There is some indication that the materials in the central filters may have become cemented. Depending upon the alternatives recommended the condition of the filters and their susceptibility to cracking should be investigated.

4.2 Final Filter Alternatives Memorandum

This memorandum presented the results of a comparison between a central filter and an upstream sloping filter for the rehabilitation of the Powerline, Vineyard Road and Rittenhouse (PVR) Flood Retarding Structures (FRSs). This memorandum includes a discussion of the project background, an overview of the existing PVR structures and filters, a discussion of potential failure modes associated with the existing filter conditions, a general “compare and contrast” of a central filter versus an upstream sloping filter, a summary of case studies, and recommendations for a filter design specific to the PVR structures.

4.2.1 Project Background

4.2.1.1 EMBANKMENT CRACKING

Numerous cracks, both longitudinal and transverse to the dam alignment, were observed in the embankments in the early 1970s after water was first impounded behind the structures. Fugro, Inc. (1979) conducted a crack investigation of the Vineyard Road FRS and NRCS (1983, 1986) conducted crack investigations of the Vineyard Road and Powerline FRSs. Mapping of cracks was also performed during installation of the central filters (Fugro for the Rittenhouse FRS and NRCS (1983, 1991) for the Powerline and Vineyard Road FRSs. General results of these crack investigations are summarized in the “Final Geotechnical Summary and Analysis Report” (AMEC 2010).

The cracking was evaluated by the NRCS, and it was concluded that the cracking did not pose an imminent danger to the structures. Ongoing surveillance of these dams and other PL-566 dams in Arizona revealed an increase in the intensity and severity of cracking over time and, as a result, an NRCS study team was appointed to study the magnitude and severity of cracking in PL-566 dams. Based on the results of these studies, the study team concluded that transverse cracks in the dams were primarily caused by tension release due to desiccation and shrinkage, and that these transverse cracks pose the greatest hazard to the integrity of the structures.

4.2.1.2 Installation of Central Filters

As a result of these findings, a phased approach was developed to further evaluate the existing condition of the dams, to design remedial measures to mitigate the cracking, and to repair the dams. Evaluations of the dams were performed by the NRCS and several geotechnical consulting firms between 1979 and 1986 and, based on the results of these investigations central filters were constructed in the three structures between 1978 and 1991. The central filters are designed to create a filter cake at the upstream interface between the filter and the embankment to prevent piping (internal erosion) along cracks that have developed in the embankment. The Powerline and Vineyard Road FRSs have filters that typically extend through the embankments and into native soils, except in a few isolated areas. In general, the central filters do not extend below the elevation of the upstream cutoff trenches. The Rittenhouse FRS filter generally does not extend through the embankment and into native soils or extend below the elevation of the upstream cutoff trench. Additionally, a central filter is not present in the southern end of the Rittenhouse FRS from Station 30+00 (the left abutment) to Station 80+00, a distance of 5,000 feet. It is the opinion of the project geotechnical engineer that the filters should extend into soils that possess Stage II cementation (or greater) and/or soils that are essentially incompressible and not susceptible to internal seepage erosion.

4.2.1.3 Presence of Collapsible Holocene Soils

The FRSs are underlain by low-density alluvial fan soils, which were deposited during the Holocene (during the last approximately 11,000 years). These soils have a high potential for collapse settlement and typically experience from 2 to 6 percent of vertical strain upon wetting under self-weight or low superimposed loads. The Holocene soils are underlain by Late Pleistocene alluvium consisting of dense or hard, highly stratified deposits. Unlike the Holocene soils, which are uncemented or exhibit discontinuous Stage I calcareous cementation, the Late Pleistocene soils typically possess Stage II or III cementation (the reader is referred to the "Final Geotechnical Summary Report" for a presentation of the cementation stages) and are essentially incompressible from the viewpoint of contributing to settlement of low embankments. It appears that the thickness of the Holocene soils varies considerably over short distances, suggesting that the top of the Pleistocene alluvium was an erosional surface with varying topography. The orientation of drainage channels during deposition of the Late Pleistocene and Holocene deposits may have differed from the orientation of the present-day drainage system.

Boring and test pit logs were reviewed to interpret the probable contact between softer, more compressible soils that are susceptible to internal erosion and the underlying cemented, essentially incompressible soils that are not susceptible to internal erosion.

Based on these profiles, it appears that not all of the soils that are susceptible to collapse and internal erosion were removed from beneath the embankments or from the upstream cutoff trenches during construction of the dams, nor do the existing central filters in the embankments extend all the way through these soils and into incompressible soils that are not susceptible to internal erosion. Compression (collapse) of the softer, uncemented soils beneath the embankments may have resulted in differential settlement and cracking of the dams. Cracks that extend to the bottom of the embankments may be in contact with erodible soils, resulting in the potential presence of internal erosion pathways along the embankment-foundation interface below the central filters.

4.2.2 Foundation Excavations and Central Filter Construction

4.2.2.1 UPSTREAM CUTOFF TRENCH

The three dams were constructed almost entirely of soils derived from upstream borrow areas, including the upstream cutoff trench, and from excavation of foundation soils below the footprint of the embankment. Excavation of the upstream cutoff trenches and excavation of the dam foundations resulted in the presence of "shelves" that generally extend 2 to 4 feet below original natural grades. It is thought that the upstream cutoff trench was designed to extend through the contact between the softer, collapse-prone soils (typically referred to as Holocene soils) and the underlying competent, cemented soils (typically referred to as Late Pleistocene soils) along the entire length of the dam alignment; however, only limited portions of the upstream cutoff trenches extend to this contact at the PVR FRSs.

Central Filters

Central filters were installed along the centerline of all three dams. The central filters in the Powerline and Vineyard Road FRS are 3 feet wide, whereas the central filter in the Rittenhouse FRS has a nominal width of 2.6 feet. Unlike the central filters in the Powerline and Vineyard Road FRSs, the filter in the Rittenhouse FRS is not continuous over the entire length of the dam nor was it designed to extend through the entire embankment into the underlying soils. Outlet drains were installed in the Rittenhouse FRS, but not at the Powerline or Vineyard Road FRSs. The outlet drains (40 in total) were constructed between Stations 80+00 and 200+00 of the Rittenhouse FRS at approximately 1,000-foot intervals along the dam or as directed by the Engineer. The outlet drains slope toward the downstream toe of the dam and are designed to provide positive drainage from the central filter.

In a May 8, 2008 ADWR Inspection Report for the Powerline FRS, it was noted that during a recent geotechnical investigation that involved excavation of a shallow trench that exposed the upper portion of the central filter, there were similarities between the filter materials and the compacted embankment soils. Photo-documentation of this condition is presented in Appendix E of the report entitled "Earth Fissure/Ground Subsidence Instrumentation Installation Report and Monitoring Plan" (AMEC 2007), Noted similarities included "soil stiffness that supported vertical trench walls and cracking that extended into the central filter material." ADWR notes that this observation is contrary to the standard of practice for granular filter design wherein the filter should be free-flowing and self-healing.

Powerline FRS

The central filter installed in the Powerline FRS in 1991 extends along the entire length of the embankment (from Stations 17+83 to 150+70). The filter has an average depth of 18 feet and a maximum depth of 42 feet. The depth of the filter was established by the NRCS on the basis of its 1986 crack location investigation.

Vineyard Road FRS

The central filter installed in the Vineyard Road FRS in 1983 extends along the entire length of the embankment (from Stations 85+00 to 360+00). As indicated on as-built plans of the filter installation, the central filter extends to depths of between 19 and 21 feet below the crest of the dam along most of its alignment, corresponding to depths of between 2.5 to 4.5 feet below the original ground surface (SCS 1983).

Rittenhouse FRS

The central filter installed in the Rittenhouse FRS in 1979 extends from Stations 80+00 to 210+00; a filter was not installed in the southern 5,000 feet of the embankment between Stations 30+00 and 80+00. The filter was designed to extend 12 feet below the crest of the dam, except where deeper cracks were observed in the trench by an onsite NRCS representative during installation of the filter. In areas where cracks extended beyond a depth of 12 feet, the filter was deepened until there was no further evidence of the presence of the crack. The central filter has an average depth of 12.8 feet between Stations 80+00 and 109+72 and an average depth of 15.8 feet between Stations 109+72 and 200+00.

4.2.3 Existing Filter Potential Failure Modes

4.2.3.1 FUNCTION OF EXISTING FILTERS

Sand and gravel filters are used to prevent internal erosion or piping of soil through cracks in embankments or foundations of hydraulic structures. Properly graded filters designed in accordance with NEH-633, Chapter 26 criteria are capable of sealing cracks. As described in above central filters were installed to varying degrees in each of the PVR structures. Since the installation of these filters, studies have revealed potential concerns about the suitability of the soils in which the filters were founded and the depth of filter penetration. These concerns, which are documented in the Final Failure Mode Analysis Report, Structures Assessment Program – Phase 1 have led to an evaluation of the potential installation of new filter systems to mitigate the known failure modes.

4.2.3.2 POTENTIAL FAILURE MODES

To evaluate the need for an updated filter system, an understanding of the potential failure modes associated with partial penetrating filters and embankment cracking was developed. There are five likely potential failure modes related to the existing filter conditions at the PVR structures. The mechanism for failure in each case is internal erosion. Due to the relatively short impoundment duration anticipated at each of the PVR structures, the development of conditions leading to a potential dam failure are considered most likely to occur over time through a series of flood events and are considered unlikely to occur during a single flood event. The five potential failure modes are summarized as follows.

Failure Mode 1 (FM-1) – Internal erosion through transverse cracks in the embankment and a defect in the central filter.

- Desiccation cracking creates voids within the embankment allowing moisture to reach the central filter. Defects in the central filter, cementation and cracking or improper filter matching, allow for embankment material to migrate downstream ultimately leading to breach failure.

Failure Mode 2 (FM-2) – Internal erosion along the interface between the foundation and erodible soils beneath the central filter at the embankment-foundation interface (not in the embankment).

- Desiccation cracking or upstream buried channels of more permeable material allows moisture to reach the foundation-Holocene interface. Since the central filter is only a partially penetrating filter, moisture is able to migrate downstream along the embankment-foundation (embankment-soil) interface, ultimately leading to a breach failure.

Failure Mode 3 (FM-3) – Internal erosion through cracks in the embankment that extend beneath the central filter.

- Desiccation cracking creates voids within the embankment soils. Since the central filter is only a partially penetrating filter (along essentially all of the Rittenhouse FRS and only minor sections of the Powerline and Vineyard Road FRSs), moisture is able to migrate downstream below the bottom of the central filter, ultimately leading to a breach failure.

Failure Mode 4 (FM-4) – Internal erosion through cracks in the embankment beneath the central filter along the erodible soils at the embankment-foundation interface (not in the embankment).

- Desiccation cracking creates voids within the embankment soils allowing moisture to reach the erodible foundation soils. Since the central filter is only a partially penetrating filter, moisture is able to migrate downstream below the bottom of the central filter through the softer, uncemented, collapse-prone soils, ultimately leading to a breach failure.

Failure Mode 5 (FM-5) – Internal erosion through cracks in the embankment (no central filter present).

- Desiccation cracking creates voids within the embankment soils allowing moisture to migrate downstream ultimately leading to a breach failure.

4.2.3.3 SUMMARY OF FAILURE MODES

Based on the existing central filter conditions, FM-3 and FM-5 are only applicable to the Rittenhouse structure. The partially penetrating central filter does not provide adequate protection from cracking through the embankment as demonstrated in FM-3. In addition, approximately 5,000 feet of the Rittenhouse structure does not contain any central filter, making the structure susceptible to FM-5.

The remaining failure modes, FM-1, FM-2 and FM-4, are applicable to all of the PVR structures. While more likely at the Powerline or Vineyard Road structures, these failure modes could potentially occur at any of the PVR structures. The likelihood is increased for the Powerline and Vineyard Road structures because of their existing central filters. At these structures the central filters extend from the crest down to the erodible soils with an average of 5 and 7.5 feet, respectively, between the bottom of the central filters and competent, essentially incompressible soils.

4.2.3.4 MITIGATION OF FAILURE MODES

In order to mitigate the failure modes presented above the installation of a new filter system is being considered as part of the PVR Rehabilitation or Replacement Project. The new filter systems should extend from the crest of the dams into the moderately to strongly cemented soils along the entire length of each structure and should include a nonwoven geotextile on the downstream side of the filter. ADWR has informed the District and the District’s various dam rehabilitation project planning and design teams that District dam rehabilitation projects involving central filters must have a downstream geotextile (or much more costly alternative components or measures) for application approvals. To date, no feasible alternative has been identified to address ADWR’s extensive concerns with central filters as part of the District’s dam rehabilitation projects. The inclusion of a geotextile in the recommendation is to ensure any potential costs are captured in the planning level cost estimate that could be incurred by the project to meet regulatory approval requirements.

The installation of a new filter system with the addition of a downstream geotextile would mitigate FM-1 and FM-5. Extending the filter into competent soils would mitigate FM-3; however, a filter match between the filter material and all encountered foundation soils would be needed to mitigate FM-2 and a filter match between the embankment materials and all foundation soils would be needed to mitigate FM-4. The use of a central filter does not mitigate FM-2 unless there is a filter match between the filter material and all foundation soils, which would be very difficult to design and construct. In addition, the presence of coarse-grained material in contact with the embankment materials in the upstream cutoff trench may result in piping and loss of material upstream of the filter. In order to mitigate FM-4, filter matches would be required between the embankment material and all foundation soils and the filter material and all foundation soils.

4.3 Filter Alternatives

Filters can be constructed several ways. Based on experience with similar flood retarding structures, the most likely alternatives for the PVR structures are a central filter or an upstream sloping filter. While both systems have the capability of mitigating the potential failure modes presented, each system has unique advantages and disadvantages and is highly dependent on the existing embankment and foundation conditions. In addition, it is noted that the upstream sloping filter concept for the PVR dams has been developed as part of this study and taken through the Failure Modes and Effects Analysis (FMEA) process. No potential failure modes for the upstream sloping filter concept were identified. If the central filter concept is to be carried forward into the final alternative selection phase of this study, it is recommended that the central filter concept first be brought to the same level of study as the upstream sloping filter concept.

4.3.1 Central Filter

Central Typical Design

The typical design of a central filter at the PVR structures would consist of two components. The first component is a granular material designed in accordance with NEH-633, Chapter 26 (NRCS 1994) to be filter matched to the embankment soils. The granular material would be placed in a loose condition in areas of existing embankment and compacted in areas of new embankment. The second component is a nonwoven geotextile placed on the downstream side of the granular material. The filter would generally be placed vertical along the centerline of the entire structure and extend from the required freeboard elevation to the elevation of competent foundation soils. In the case of the PVR FRSs, the existing central filter trenches would be excavated through to remove the existing filter material and extend the trench down to competent foundation soils. Competent foundation soils along the PVR FRSs are considered to be those soils with Stage II cementation or greater, which are commonly considered to be Late Pleistocene soils in the PVR area.

In addition, the required freeboard elevation for the PVR FRSs will require a crest raise. In order to facilitate this raise, a portion of central filter near the existing crest would be extended upstream, horizontally for a short distance before extending vertically at the new centerline. During a February 16, 2012 FMEA, it was suggested that the horizontal portion of the filter could be eliminated by overlapping the two vertical sections of filter. This would result in an upstream-downstream gap between the two sections of vertical filter. A potential failure mode was identified whereby a crack could propagate downstream from the partially penetrating upstream vertical filter over the top of the downstream vertical filter. The FMEA participants did not elect to carry this failure mode forward for further discussion and categorization, since other alternatives were proposed that would eliminate this condition.

4.3.2 Upstream Sloping Filter

Upstream Sloping Filter Typical Design

The typical design of an upstream sloping filter at the PVR FRSs would consist of a granular material designed in accordance with NEH-633, Chapter 26 (NRCS 1994) with a nonwoven geotextile placed on the downstream side of the filter material (see Figure 11). The filter would be placed along the entire upstream slope of the structure and extend from the required freeboard elevation down to competent soils as describe in Section 5.1.1. A portion of the upstream slope extending from the existing crest down throughout the upstream toe and terminating into competent soils would be excavated. A nonwoven geotextile would be placed on the slope, followed by placement of compacted filter material extending from competent foundation soils to the required freeboard elevation. The filter would then be covered with filter-matched embankment material.

4.4 Recommendations

Based on experience with filter construction, the major advantages to installing a central filter are the limited quantity of excavation required and the flexibility of construction sequencing. Central filter excavations result in a limited quantity of excavation because the only overexcavation occurs at the crest above the freeboard elevation, thus reducing the overall cost of construction. Central filters also provide flexibility in construction sequencing because excavation and backfill can be performed in tandem. This allows for the process to start and stop as needed with a limited section of excavation open at any given time. However, given the anticipated foundation soil conditions at the PVR structures and the inability to address all of the potential failure modes, the project geotechnical engineer (AMEC) believes the advantages of a central filter are greatly diminished.

The PVR embankments are underlain by 5 to 7.5 feet of erodible soils on average, and these erodible soils are as thick as 15 feet in some areas of the embankment. The contact between these erodible soils and the underlying competent soils is not marked by an abrupt change in character; rather, the contact is gradational and not easily observable from the crest of the dam. In addition, the structures have been constructed over a number of paleochannels (relic washes) that are more prone to sloughing. The potential for cave-ins, whether a result of loose soils or coarse-grained paleochannel deposits, could easily increase construction costs, especially given that the PVR FRSs have a combined length of approximately 11.5 miles. The presence of these materials would also introduce unmatched filter gradations.

If the final alternative selection for the PVR Rehabilitation or Replacement Project requires rehabilitation of the existing structures, AMEC recommends the construction of an upstream sloping filter. The filter system should consist of a downstream geotextile and filter-matched granular material. This type of filter would allow inspectors to more easily identify the subtle differences between erodible soils and cemented, competent soils, avoid the potential for substantial additional work resulting from cave-ins and the costs associated with this additional work.

5. GEOHAZARD

This section provides a summary of the geohazard reviews, investigations and analyses for the PVR project. The reader is referred to the full geohazard reports for further details and information in regards to the PVR structures.

The geohazard studies are documented in the following reports

- "Powerline, Vineyard Road and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project Final Initial Subsidence and Earth Fissure Report". (AMEC August, 2010).
- "Powerline, Vineyard Road and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project Final Earth Fissure Risk Zoning Memorandum". (AMEC May, 2012)

5.1 Final Initial Subsidence and Earth Fissure Report (GeoHazard Study)

The purpose of the geohazards investigation was to evaluate potential impacts of ground subsidence and earth fissuring on the selection and subsequent development of rehabilitation designs and/or replacement alternatives for flood protection afforded by the Powerline, Vineyard Road and Rittenhouse Flood Retarding Structures (FRS). The results, findings and conclusion of the report were used by the project team in its development and evaluation of dam rehabilitation and/or replacement alternatives.

The geohazard study and assessment involved the compilation, review and interpretation of existing technical data. This data included review of aerial photography and interferometric satellite-based synthetic aperture radar (InSAR) data, ground reconnaissance of the study area, surface resistivity surveys, development of subsidence predictions, and a preliminary delineation of earth fissure risks.

Existing Data Collection & Review

Available groundwater data were reviewed and a summary of historical groundwater decline in the project area was prepared. Included in this effort was review of the East Valley Water Forum scenarios for the east Salt River Valley sub-basin application of the Regional Groundwater Flow Model and the impact of the proposed Superstition Mountains Recharge Project on the Central Arizona Water Conservation District.

InSAR Review and Analysis

InSAR was used in this study to detect the rate and distribution of subsidence occurring in the study area over the time periods covered. This information was then further utilized in the characterization of bedrock/alluvial interface and deep alluvium and for the FRZ delineation

ADWR is currently applying InSAR as part of a long-range study of basin subsidence in Arizona. Recent interferograms developed by ADWR on the basis of 2000 to 2009 synthetic aperture radar data were compiled and analyzed for the project area. InSAR images previously provided by ADWR were also reviewed as part of this assessment.

Photogeologic Interpretations

High-resolution aerial digital imagery previously provided by the District was reviewed, and it proved to be an equivalent substitute for low-sun-angle afternoon photography. Lineament analyses using both low-sun-angle aerial photography and high-resolution digital aerial imagery for the purpose of identifying potential earth fissures have been performed at Powerline FRS by AMEC in previous studies.

As part of the current study, aerial photographs and digital images were evaluated for purposes of identifying features indicative of the presence of earth fissures. These features include elongated fissure gullies, alignments of potholes and other small depressions, lineations in the vegetative cover and subtle linear ground features caused by shading. No conclusive evidence for earth fissuring was identified, except for the known earth fissure downstream of the Powerline FRS embankment at about Station 115+45 and the known earth fissures in the vicinity of Hawk Rock to the west of the Powerline FRS.

Geologic Reconnaissance

A ground reconnaissance was performed to inspect the project area for evidence of ground subsidence or earth-fissure-related features. Select lineaments within the study area with the potential to impact proposed facilities were observed from the ground. Very few lineaments outside of the immediate vicinity of Powerline FRS were selected for direct ground observation. No earth fissures or features indicative of possible earth fissures were observed at the project site, excepting previously known earth fissures in the vicinity of the Powerline FRS and Hawk Rock. As a consequence, slight adjustments were made to the alignment of some of the features and other features were eliminated, particularly features that were identified as being cultural in origin.

Deep Resistivity Profiling

Resistivity interpretations do not result in unique solutions; therefore, the interpreted results are approximate. However, reasonable trends are apparent that can assist in understanding the basin subsurface. Two-layer interpretations, typically used for a shallower and deeper interface, were performed. Shorter array spacing data were used to develop two-layer interpretations of the shallower subsurface. The longest array spacing data were used to develop two-layer interpretations in the deeper subsurface, and when appropriate, for an intermediate interface or to check against the possibility of high-resistivity deep bedrock. These interpretations provide general resistivity values and ranges of anticipated depth interfaces within the basin subsurface to depths of several hundred feet to as great as about 1,000 feet.

Future Subsidence Prediction

Based on the subsurface information available from literature, existing geophysical well logs and from the surface geophysical measurements, simplified basin vertical profiles were developed to estimate historic subsidence and the potential for future subsidence. It was assumed that basin material compression leading to subsidence was limited to the portions of the upper or middle alluvial units that were below the groundwater table; contributions of bedrock or the lower alluvial unit were assumed to be negligible. Estimates of subsidence could then be calculated from the resulting basin vertical profiles.

Based on these profiles, simplified estimates of subsidence were performed using the methods and procedures discussed in the AMEC white paper “Characterization for Subsidence Modeling and Percolation Theory–Based Modeling of Subsidence”.

Earth Fissure Risk Delineation

Using the data and analytical techniques discussed above, earth Fissure Risk Zones (FRZ) were developed. The risk zones were first delineated for the Powerline FRS and the northern portion of the Vineyard Road FRS as part of a previous investigation. The risk zones were then updated to account for the earth fissure discovered downstream of the Powerline FRS embankment at about Station 115+45. The risk zones around the Powerline FRS, the proposed Powerline IDSM and the northern third of the Vineyard Road FRS did not change as a result of this investigation. However, the earth FRZ were extended south to include the remainder of the Vineyard Road FRS and the Rittenhouse FRS and extended north to include the Powerline Diversion.

5.1.1 Geological Setting

The project site is within the Sonoran region of the Basin and Range physiographic province and is, in part, structurally separated from the central Phoenix valley by the bedrock highs of the Tempe Butte area. The study area lies within the Mesa-Chandler sub-basin, adjacent to the Superstition and Goldfield Mountains, which are composed of metamorphic and igneous bedrock. This sub-basin contains basin-fill deposits of the Salt River Valley that can be subdivided into three units: lower alluvial unit (LAU), middle fine-grained unit (MFGU) and upper alluvial unit (UAU).

The surficial geology for the PVR project is discussed in the *Draft Supplemental Earth Fissure Risk Technical Memorandum* prepared by AMEC on behalf of the District. The following sections discuss aspects of the geologic setting important to an appraisal of ground subsidence and earth fissuring, such as depth to bedrock and deep alluvial characteristics.

Basin Geometry and Depth to Bedrock

The buried shape and proximity of the bedrock-alluvium contact are likely the most dominant influences on where earth fissures form around Hawk Rock and near the Powerline FRS. These are regions where the gradient of the bedrock-alluvium interface is quite pronounced, with the thickness of the alluvium being variable. These conditions result in a differential subsidence profile, a prerequisite to earth fissure formation. Bedrock is present at the surface at Hawk Rock, which is about 4,000 feet west of the bend in the FRS embankment near Station 110+00. Understanding this bedrock geometry is one of the most important factors for delineating earth fissure risks for the project.

There are four data sets that either directly or indirectly estimate the depth to bedrock or shape of the bedrock-alluvium interface in the vicinity of the project: 1) Bouguer gravity data, 2) depth to bedrock, 3) bedrock elevations, 4) InSAR, and 5) geophysical measurements.

Bouguer Gravity Data

The Bouguer gravity anomaly represents corrected surficial gravity measurements. Differences in the data represent differences in subsurface density. The most significant variation in subsurface density is that between bedrock and overlying alluvium.

The gravity data indicate that the depth to bedrock increases to the north and northeast of Hawk Rock. These data also indicate that the depth of bedrock and basin thickness increases to the south and southeast of Hawk Rock.

ADWR is currently preparing a three-dimensional (3D) model of gravity data for the Superstition Vistas area. This study includes the project and Hawk Rock areas. The gravity data analyzed for the ADWR study represent a much greater density of data than obtained from previous studies and includes historical gravity data acquired by the USBR and USGS in the vicinity of Hawk Rock and the Powerline FRS.

Laney and Hahn Depth to Bedrock

The depth to bedrock developed by Laney and Hahn is based on limited data from wells drilled in the area, geologic mapping and gravity data. These data were developed on a regional scale and do not reflect local variations in the depth to bedrock. This interpretation does provide a reasonable estimation of the depth of the bedrock-alluvium interface on a large scale, but the presentation does not show variations at a scale that is useful for delineating earth fissure risk.

The depth to bedrock presented in Laney and Hahn provides a better indication of the depth to bedrock than provided from Bouguer gravity data alone. However, the Laney and Hahn work is concerned mainly with broad, regional variations, and the 400-foot contour interval used is relatively large. Those data also indicate that the depth to bedrock is increasing to the northeast and south of Hawk Rock. The data indicate that the depth to bedrock is relatively shallow in the vicinity of the Powerline FRS and the Powerline FRS IDSM and increases to depths greater than 1,200 feet for most of the Vineyard Road FRS alignment, for the entire length of the Rittenhouse FRS, and along the Powerline Diversion.

USBR Bedrock Elevation Data and Well Data

As part of the original investigations of subsidence and earth fissuring for the CAP Canal that were performed by the USBR and USGS, contours of bedrock elevation were developed for the area around Hawk Rock, including much of the area around the Powerline FRS and the northern portion of the Vineyard Road FRS. These contours were developed from an interpretation of deep seismic refraction and gravity surveys performed by the USGS and USBR. These data were never finalized and did not undergo a full review process. However, the contours do provide an informed and valuable local interpretation of the shape of the bedrock-alluvium interface in this portion of the project. For purposes of the following discussion, the ground surface in the area is assumed to be at an elevation of 1,500 feet. Actual elevations within the project area generally range from an elevation of 1,560 feet in the vicinity of the CAP Canal to an elevation of over 1,600 feet at the Rittenhouse FRS crest.

The USBR data indicate that the depth to bedrock at the bend in the Powerline FRS embankment at about Station 110+00 is about 300 feet below the ground surface (bgs). It should be noted that more dense or more cemented material was encountered at a depth of 330 feet bgs, and schist bedrock was encountered at a depth of 335 feet bgs.

The USBR data indicate that the depth to bedrock from about Powerline Station 50+00 to 105+00 ranges from about 600 to 700 feet bgs, and that north of Station 110+00 the depth to bedrock increases rapidly. These data indicate that depth to bedrock increases very rapidly south of the Powerline FRS. Underneath the northern portions of the Vineyard Road FRS, the depth to bedrock ranges from about 800 feet bgs at Station 345+00 to about 1,700 feet bgs at Station 310+00 to approximately 1,500 feet bgs at Station 280+00. The next deep well to the southeast at about Vineyard Road FRS Station 271+00, encountered conglomerate at a depth of 650 feet bgs and granite at a depth of 1,770 feet bgs. Southward from this point, the data indicate that depth to bedrock continues to increase to depths greater than 2,000 feet bgs.

InSAR

InSAR provides what is probably the best indication of the shape of the bedrock-alluvium interface in the vicinity of Hawk Rock due to its full map-view and 3D coverage. The most important aspect of this is the indication of the presence of buried bedrock ridges that radiate outward from Hawk Rock and how those implied buried ridges relate to the location of known earth fissures. Most of the known earth fissures and all the known fissures not in the immediate vicinity of Hawk Rock follow the apparent crest of these implied buried ridges. When comparing the InSAR data and USBR bedrock elevation data, it appears that the InSAR data more accurately indicate the location of the implied buried ridges.

Geophysical Measurements

As part of previous and ongoing investigations in the Powerline FRS area, geophysical studies provide some indirect measurement of the depth to bedrock. As important to the detection of bedrock in the subsurface profile are measurements that do not indicate bedrock is present within the depths of investigation.

As part of this study, a deep resistivity sounding was performed at about the Powerline IDSM Station 21+00. The interpreted depth to bedrock from this sounding is approximately 1,000 feet bgs. Several deep resistivity profiles and deep ReMi profiles were performed as part of the *Earth Fissure Risk Zone Investigation Report, Powerline and Vineyard Flood Retarding Structures, Pinal County, Arizona* (AMEC 2006). A resistivity profile centered north-south on Powerline FRS Station 135+00 indicates that the depth to bedrock may be greater than 1,000 feet bgs, while a profile centered north-south on Powerline FRS Station 115+00 does not indicate bedrock within a depth of investigation of about 300 feet bgs. Deep ReMi profiles performed at about Powerline FRS Stations 85+00, 110+00, 115+00 and 135+00 indicate that the depth to bedrock is greater than 300 feet bgs at each of those locations.

Other deep resistivity soundings performed as part of this investigation did not indicate bedrock within the depth of investigation of approximately the greatest electrode spacing of 1,000 feet. Those results are consistent with the historic deep wells SG-6, SG-10 and SG-12, where bedrock was encountered at depths greater than 1,600 feet, or not encountered at all,

5.1.2 Deep Alluvium Characteristics

The magnitude of ground subsidence and the location of earth fissures throughout the project area are controlled by the interactions of groundwater decline and the material characteristics of the compressible alluvial basin materials on the geometry of the underlying alluvial sediment/bedrock interface. The thickness of the basin alluvial materials is highly variable across the project area, ranging from none at Hawk Rock (less than 1 mile west of the Powerline FRS) to depths of 1,600 feet bgs at the southern end of the Vineyard FRS and 2,000 feet bgs at the Rittenhouse FRS. Variations in subsidence appear to reflect variations in both the depth to bedrock and the composition of the deep basin materials.

Areas of minimal subsidence include the vicinity of Station 110+00 on Powerline FRS and the vicinity of Station 292+00 on Vineyard Road FRS. While shallow bedrock is clearly an influence at Powerline FRS Station 110+00, shallow bedrock does not appear to be present at or near Vineyard Road FRS Station 292+00 to minimize subsidence in that area. Even though deeper bedrock depths provide more presumably compressible alluvial materials under the Vineyard FRS compared with the Powerline FRS, considerably more subsidence is occurring in the vicinity of the Powerline FRS. Furthermore, subsidence is continuing in the vicinity of the Powerline FRS where groundwater table depths are likely below the top of bedrock and the compressible basin alluvium is probably above the regional groundwater table.

Data available to characterize the material characteristics of the deeper alluvium in which ground subsidence occurs are limited primarily to those data derived from surface geophysics and several deep exploration wells completed by the USGS during CAP Canal investigations. Several deep exploration wells were completed by the USGS to measure alluvium thickness of the basin sediments. Information from these wells is discussed below.

Subsidence Characteristics of Alluvium

Subsidence magnitudes are both a function of groundwater level decline and alluvial material properties. Bell has reported typical subsidence rates of 1 foot of subsidence per 20 feet of groundwater level decline in clay-rich basin sediments, and 1 foot of subsidence per 40 to 60 feet of groundwater decline in more clastic basin alluvium materials. Local experience in basin alluvium characterization and modeling has verified both greater subsidence magnitudes and time-delay effects in subsidence relative to regional groundwater level declines in clay-rich alluvium of the MFGU sediments as compared to the mixed alluvium of the UAU. It also appears that significantly smaller to negligible contributions to subsidence occur in the older LAU. When not internally drained by pumping within the MFGU, time delay in subsidence of several too many years occurs due to low permeabilities in the clay-rich MFGU material that slow the process of internal pore pressure change that controls consolidation. However, when internally drained by pumping within the MFGU, rapid large-magnitude subsidence can result as “water of compaction” is removed. Removal of such “water of compaction” from silt and clay materials in an aquitard probably results in a mostly nonrecoverable reduction in pore volume that is manifested as ground subsidence.

5.1.3 Hydrogeological Conditions

Historic hydrographs of selected wells in the study area were reviewed. Historically, the groundwater in the project study area has declined significantly due to well withdrawals far exceeding natural recharge, as analyzed and discussed in previous reports. This decline likely commenced in the late 1940s as agricultural development began in earnest in the east valley. A reasonable estimate of predevelopment groundwater levels can be made from Well (D-01-08)15CCC, which had a groundwater elevation of about 1,325 feet amsl (water level depth of approximately 275 feet) in the late 1930s to early 1940s.

Multiple wells capable of moderate to high production rates are found throughout the study area, some of which are within 1 mile of the FRS facilities. Yields in these wells are often high, with discharges of 2,000 gallons per minute not uncommon. Transmissivities of the LAU, the probable screened intercept in many of the large-capacity wells, are reported to range from about 1,000 to 50,000 square feet per day (Laney and Hahn 1986). The average depth of the 76 active water wells within the study area is about 1,040 feet bgs, and well depths range from 651 to 2986 feet bgs.

Water level data for many of the wells in the historical database may or may not represent general head distributions in the region in which these wells are located. Operating wells have local cones of depression that may be reflected in the reported water level readings. Such detail cannot be ascertained from the historic records. However, several of the historical hydrographs are for piezometers that were installed as part of the CAP Canal project. These are not pumping wells and should be more representative of the general groundwater levels at those locations along the CAP Canal. These piezometer installations were also typically nested so that changes in the total piezometric head at various depths in the alluvium have been monitored. However, an apparent discrepancy present in readings show a difference of about 100 feet in water level, was recorded between the nested piezometers prior to 2002. This apparent discrepancy was not present by 2006. It is not known if a correction has been made to the more recent data, possibly by adjusting the deeper piezometer to match the shallow piezometer, or if connection between the deep and shallow piezometers has developed over time.

The general trends in water levels for the years 1978 and 2009 across the study area, and the influence of major pumping centers that impacted those trends were reviewed. In 1978, groundwater levels at the northern and southern ends of the study area had dropped over 200 feet from the estimated predevelopment level, and were roughly 500 feet bgs (elevation about 1,100 feet amsl). In the middle of the study area, groundwater levels had dropped less, and were up to about 70 feet higher than in the surrounding area. Suburban growth in the vicinity north of the Powerline FRS, and the establishment of major agriculture to the southwest and west of the Rittenhouse FRS, were probable reasons for the development of major pumping centers in 1978.

By 2009, the water level trend across the PVR study area had changed significantly. Continued suburban development around the northern part of the study area had resulted in continued pumping of groundwater with a further groundwater level decline to nearly 600 feet bgs. Replacement of pumped groundwater by CAP water delivery for agricultural use resulted in significantly reduced pumping and recovery of groundwater levels by as much as about 80 feet from the 1980s to the present at the southern end of the study area. Groundwater levels remained stable and declined moderately (perhaps up to about 40 feet of decline from the 1970s to the present) through the Vineyard Road FRS section of the study area.

Proposed Superstition Mountains Recharge Facility

If constructed, the proposed Superstition Mountains Recharge Facility, located south of the Project study, area will use CAP water delivered to surface infiltration ponds adjacent to Queen Creek to recharge the regional groundwater aquifer. At full build-out, it is anticipated that CAP water will be recharged at the facility at a rate of 56,500 acre-feet per year for 20 years, after which the storage permits for additional recharge would be renewed. Results of modeling by Montgomery and Associates indicate that the recharge will impact groundwater levels throughout the project study area. After 20 years of operation 2030 groundwater levels are projected to rise above baseline levels by nearly 100 feet at the south end of the Rittenhouse FRS, more than 50 feet at the south end of the Vineyard Road FRS, and nearly 50 feet at the Powerline FRS and the north end of the Vineyard Road FRS. By the year 2100 groundwater levels are projected to rise above baseline levels by about 200 feet at the south end of the Rittenhouse FRS, about 125 feet at the south end of the Vineyard Road FRS, and about 50 feet at the Powerline FRS and the north end of the Vineyard Road FRS.

Estimated Future Conditions

Current groundwater modeling scenarios developed by ADWR for the east Salt River Valley provide estimated future groundwater conditions on which to base future predictions of land subsidence. Two primary scenarios were evaluated and used for predictions of future subsidence to the years 2030 and 2100. The “base case scenario” was a future projection with no recharge occurring at the Superstition Mountains Recharge Facility and Scenario 2 was a projection with an operational Superstition Mountains Recharge Facility. Presentation of results included change-in-water-level contours plotted on figures with township boundaries for location reference; results obtained from these figures were considered to be approximate. For this evaluation, the modeled water level changes were estimated for five locations along the CAP Canal and FRS through the study area using the ADWR estimates. These locations are at the southern end of the Rittenhouse FRS, the southern end of the Vineyard Road FRS, SG-6 along the Vineyard Road FRS, the northern end of the Vineyard Road FRS, and the Powerline FRS IDSM alignment Station 20+00. These water level changes are summarized below. Results of the more recent Superstition Mountain Recharge Facility modeling are also summarized below.

Modeled Groundwater Levels by Others for Future Subsidence Scenarios

Location	Change in Groundwater Level, feet			
	Base Case Scenario - No Recharge Facility		Scenario 2 - With Recharge Facility	
	2030	2100	2030	2100
Powerline FRS IDSM Station 20+00	-25	-100	+50	+0 (+30)
North Vineyard Road FRS Station 350+00	0	0	+50	+50
Vineyard Road FRS Station 271+00, Well SG-6	+50	0	+50	+100 (+80)
South Vineyard Road FRS Station 90+00, Well SG-10	+80	0	+50	+150 (+125)
South Rittenhouse FRS Approximately Station 50+00	+100	0	+100	+200

Note: Groundwater level changes in parentheses are from more current 2009 modeling.

5.1.4 Discussion

Known Earth Fissures

There are known earth fissures in the Project area near Hawk Rock and one known earth fissure located immediately downstream of the Powerline FRS embankment at about Station 115+45. There also is a high probability that the earth fissure near Station 115+45 extends beneath the existing embankment. It is suspected that subsidence patterns at the Powerline FRS will continue into the future, potentially causing further development of fissures in this area.

The earth fissures in the vicinity of Powerline FRS and Hawk Rock appear to follow along or near the crest of buried ridges that radiate from Hawk Rock. The InSAR data show the locations of the implied buried ridges. Previous investigations have included continuous seismic refraction profiling for the purpose of identifying concealed earth fissures. Continuous seismic profiling has occurred along the proposed Powerline IDSM alignment and much of the alignment of Powerline FRS. Other than the earth fissure at about Powerline FRS Station 115+45, there are no known earth fissures in close proximity to the components of the project. It is noted that this earth fissure may be an extension of the known earth fissure located about 700 feet west of the Powerline FRS embankment on the west side of Ironwood Road.

Estimated Historical Subsidence

Estimated Historic Subsidence 1940 to 2010

Location	Estimated or Measured Subsidence, feet		
	Estimated 1940 to 2010	Measured (approximate)*	Estimated at Profile Section (1 mile offset from location)
Powerline FRS IDSM Station 20+00	4.0	1986 to 2007 1.4**	3.1
North Vineyard Road FRS Station 350+00	1.6	1986 to 2007 0.6	1.0
Vineyard Road FRS Station 271+00, Well SG-6	0.8	1971 to 2001 0.5	0.5
South Vineyard Road FRS Station 90+00, Well SG-10	3.4	1971 to 2007 1.1	2.8
South Rittenhouse FRS Approximately Station 50+00	4.1	1971to1983 0.5	3.3

* Measurements are commonly combined multiple points measured over different time spans.

** Measured at Powerline FRS Station 130+00, about IDSM Station 0+00.

Predicted Future Subsidence

Future subsidence appears to be largely influenced by two factors, time-delayed unfinished subsidence from past or current groundwater declines, and future groundwater declines. Current and future groundwater declines are occurring or modeled to occur in the future only at the extreme northern end of the study area, which could result in impacts on the Powerline FRS. Groundwater levels throughout the rest of the study area are predicted to remain stable or rise in the future. The largest rise in groundwater levels is predicted to occur in the southern portion of the study area. Predicted future subsidence relative to current ground elevations are summarized below. Using current groundwater level model results, anticipated future subsidence in the study area could be greatly subdued compared to historic rates.

Future Subsidence Predictions by Scenarios

Location	Estimated Future Subsidence (feet)			
	Base Case Scenario - No Recharge Facility		Scenario 2 - With Recharge Facility	
	2030	2100	2030	2100
Powerline FRS IDSM Station 20+00	0.3	1.0	0.1	0.3
North Vineyard Road FRS Station 350+00	0.4	0.6	0.3	0.5
Vineyard Road FRS Station 271+00, Well SG-6	0.3	0.5	0.3	0.5
South Vineyard Road FRS Station 90+00, Well SG-10	0.0	0.2	0.0	-0.1

Future Subsidence Predictions by Scenarios (continued)

Location	Estimated Future Subsidence (feet)			
	Base Case Scenario - No Recharge Facility		Scenario 2 - With Recharge Facility	
	2030	2100	2030	2100
South Rittenhouse FRS Approximately Station 50+00	-0.1	0.2	-0.1	-0.2

Earth Fissure Risk Delineation

The risk zones were first delineated for the Powerline FRS and the northern portion of the Vineyard Road FRS as part of a previous investigation. The risk zones were then updated to account for the earth fissure discovered downstream of the Powerline FRS embankment at about Station 115+45. The risk zones were further discussed in relation to the proposed Powerline IDSM. The risk zones around the Powerline FRS, the proposed Powerline IDSM and the northern third of the Vineyard Road FRS did not change as a result of this investigation. However, the earth FRZ was extended south to include the remainder of the Vineyard Road FRS and the Rittenhouse FRS and extended north to include the Powerline Diversion. The definitions for the earth FRZ are presented below.

FRZ 1: Earth fissures are present and will likely continue to occur in the future as evidenced through the application of multiple investigative methods, including published and unpublished mapping, photolineament analysis, geophysical surveys, ground reconnaissance and trenching.

FRZ 2: Conditions for the past development of earth fissures are present through multiple lines of evidence; however, earth fissures have not been positively identified. A high probability of future development of earth fissures is present. Evidence supporting the possible presence of concealed fissures and probability of development of fissuring in the future includes strain calculations and predictions from subsidence modeling, InSAR and geodetic survey data, and photolineament analysis, as well as proximity to and trends of known earth fissures and the presence of known seismic anomalies, soil discontinuities and large transverse cracks in the FRS embankments.

FRZ 3: A probability of future earth fissure formation is present, but the risk is less than in FRZ 2, unless future differential subsidence occurs in FRZ 2, coupled with the currently elevated horizontal tensional strain. Evidence supporting this designation includes InSAR data, photolineament analysis, subsidence modeling and geodetic survey data.

FRZ 4: A low probability of future earth fissure formation exists. Evidence suggests that no significant tensional strain will develop from future subsidence.

A portion of the Powerline FRS embankment is located in FRZ 1 and in FRZ 2. Portions of the Powerline FRS, the proposed Powerline IDSM, and the Vineyard Road FRS are located within FRZ 3. The Rittenhouse FRS, the Powerline Diversion, most of the Vineyard Road FRS, and portions of the Powerline FRS are located within FRZ 4.

The earth FRZ were approximated to reflect the earth fissure risk posed to the project through 2025, should current subsidence trends continue. To be conservative, the earth fissure risk delineations do not anticipate recharge from the proposed Superstition Mountains Recharge Facility. Recharge from the proposed facility would likely not affect the risk delineation in the vicinity of Powerline FRS, but it may have an effect on the risk delineation at Vineyard Road FRS.

5.1.5 Conclusions and Recommendations

The major concern relating to subsidence and earth fissuring is focused on the Powerline FRS. There is a known earth fissure immediately downstream of about Powerline FRS Station 115+45, and there is a high probability that the earth fissure is also present beneath the FRS embankment. The earth fissure risk is highest in the area around the Powerline FRS and the portion of the Vineyard Road FRS located in FRZ 3.

Predicted future subsidence is greatest in the area of the Powerline FRS, particularly portions to the north of the bend at about Powerline Station 110+00. Subsidence is predicted to continue in this area and will complicate future plans regarding the Powerline Diversion as it could potentially impact the grade of the channel and make draining water to the south challenging. Any future alternative options that require moving water from north to south in this area will also have to address the potential that future subsidence will impact the grade of channels or other infrastructure. Future subsidence predictions indicate that the potential for 1 to 2 feet of additional subsidence is likely in area north of about Powerline Station 110+00 and along the proposed IDSM alignment.

Other portions of the project are not anticipated to experience large amounts of subsidence in the future, and are anticipated to have a low risk for development of earth fissures. Results of this study indicate that the portion of the Vineyard Road FRS located in FRZ 3 may have a lower risk for earth fissures than previously thought. It is recommended that the District consider performing a future investigation to determine if the earth fissure risk in this zone is less than currently classified. It is recommended that any future investigation performed include close evaluation of available monitoring data, additional InSAR analysis, additional geophysical profiling, additional subsidence prediction, and updating the stress-strain model in this area.

5.2 Final Earth Fissure Risk Zoning Memorandum

The purpose of this memorandum was to address NRCs comments about subsidence and earth fissure risk zoning at the Powerline, Vineyard Road and Rittenhouse (PVR) Flood Retarding Structures (FRSs) as they relate to the PVR FRS Rehabilitation or Replacement Project. This memorandum starts with a general discussion of ground subsidence and earth fissuring due to groundwater withdrawals. This is followed by discussions of the investigative and modeling methods used to predict future subsidence and the risk of earth fissuring, and the history of earth fissure risk zoning at flood control structures in the Phoenix area. The memorandum culminates with a discussion of earth fissure risk zoning at PVR and responses to specific questions that NRCS has posed regarding PVR earth fissure risk zoning.

5.2.1 Subsidence and Earth Fissuring Due To Groundwater Withdrawal

Land subsidence and the development of earth fissures at the PVR FRSs, and at other flood control structures in the Phoenix area, are primarily a result of groundwater level declines..

Subsidence

Lowering the groundwater elevation in a column of alluvial basin material increases the effective stress and loading on the material column. If the column consists of granular materials, typically sands and gravels, compression of the material below the initial water level takes place rapidly. Until granular particle contact points are changed by compression, at least some of the compression can be recovered elastically if water levels rise and the effective stress is decreased. Compression that results from particles slipping or crushing tends to have much less elastic rebound. If the material column contains a significant fraction of fine-grained materials, such as clay, consolidation of the material below the initial water level takes place more slowly. The time frame of consolidation is a function of the permeability of the material, where lower permeability increases consolidation time. Consolidation is also a function of the distance to and the interconnectivity of higher permeability zones which can relieve the excess pore pressure by draining water from clay-rich materials. Greater distances to permeable drainage zones increase the consolidation time. Although consolidation increases can be modeled as an elastic phenomenon, consolidation does not typically recover with a decrease in loading.

Earth Fissure Development

Where differential rates and magnitudes of subsidence occur over relatively short distances, horizontal strains can become sufficient to cause earth fissuring. Jachens and Holzer (1979, 1982) evaluated the threshold tensile strains for fissuring based on studies in the Eloy-Casa Grande area of central Arizona. Jachens and Holzer (1982) concluded that most fissuring occurs at horizontal tensile strains in the range of 0.02 to 0.06 percent. This compares with threshold strains for cracking of compacted clays zones in dam embankments (or compacted clay liners) of about 0.1 to 0.3 percent (Leonards and Narain 1963; Covarrubais 1969).

Earth fissures in alluvial aquifers that have experienced large groundwater declines are likely associated with a process termed generalized differential compaction (Carpenter 1994). Three mechanisms are likely at play in the formation of fissures. These mechanisms include: 1) bending of a plate above a horizontal discontinuity in compressibility (Lee and Shen 1969), 2) dislocation theory representing a tensile crack (Carpenter 1994), and 3) vertical propagation of tensile strain caused by draping of the alluvium over a horizontal discontinuity in compressibility (Haneberg 1992). Due to these probable mechanisms, fissures commonly develop along the perimeter of subsiding basins, often in apparent association with exposed bedrock or shallow buried bedrock, suspected mountain-front faults, or distinct facies changes in alluvial materials.

Role of Groundwater Level Changes

One of the most important parameters for delineating earth fissure risk is groundwater declines, specifically, future groundwater declines. If groundwater declines do not occur, then significant subsidence will not occur. However, predicting future groundwater declines is particularly challenging due to the social-political factors that drive groundwater use. As a result, accurate prediction of future groundwater withdrawal is not possible. Related to this challenge is the influence of groundwater recharge facilities. To date it is unclear how recharge facilities impact subsidence. It’s well understood that in the immediate vicinity of a recharge facility groundwater levels increase; however, how that increase influences more regional-scale groundwater elevations is less certain. Also uncertain are the overall operation of recharge facilities and the long-term availability of excess water for recharge. Other uncertainties are the socio-political impacts of recharge facilities.

The future behavior of groundwater elevations remains one of the most challenging and uncertain parameters to quantify and delineate earth fissure risks. These uncertainties tend to result in more conservative delineation of the potential risks in order to reduce the risk imparted by the uncertainties.

5.2.2 Investigative and Modeling Methods

Investigative Methods

There is a lack of published guidelines for the delineation of earth fissure risks, with the first guideline document for subsidence and earth fissure investigations being published in 2011 (Arizona Land Subsidence Interest Group 2011). Most of the investigative techniques and guidelines in this document were pioneered by AMEC as part of their work on District projects throughout the Phoenix area. The investigative methods have evolved through time and the Initial Subsidence and Earth Fissure Report, PVR Planning Study (AMEC 2010b) and the Supplemental Earth Fissure Risk Report, Powerline FRS Interim Dam Safety Measure (AMEC 2010c) represent the most recently completed, large-scale subsidence and earth fissure investigations in the Phoenix area as of the publication of this memorandum.

Detailed discussions of the methodologies utilized are included in these reports. In addition, AMEC has recently developed Procedural Documents (AMEC 2011b) that describe in detail the procedures for 11 methods of investigation for earth fissure risk delineation.

Modeling Methods

Sub-basins in the Salt River Valley are generally subdivided into three alluvial units: the upper alluvial unit (UAU), the fine-grained middle alluvial unit (MAU), and the lower alluvial unit (LAU) Prokopovich 1983; Laney and Hahn 1986). In order to model future subsidence, simplified basin vertical profiles are developed to estimate historical subsidence and predict the potential for future subsidence. Within the Phoenix area, it is assumed that basin material compression leading to subsidence is limited to the portions of the UAU and/or MAU that are below the groundwater table (i.e., saturated). Estimates of subsidence are then calculated using the basin vertical profiles.

Based on these profiles, simplified estimates of subsidence are performed using the methods and procedures discussed in AMEC’s white paper “Characterization for Subsidence Modeling and Percolation Theory–Based Modeling of Subsidence” included in Appendix E of the Initial Subsidence and Earth Fissure Report (AMEC 2010b). Calculation of subsidence is based on a concept of increased loading due to falling groundwater levels with resulting increases in effective stress on the compressible sections of basin alluvium (each section is typically 100 feet in thickness) whose compression (and resulting ground subsidence) is a function of the moduli of the basin alluvium sections. This approach uses percolation theory (PT) to model relationships of basin density and modulus in basin alluvial sections. The resulting modulus profiles are variable (increasing with depth) and nonlinear through the compressible section of the basin alluvial profile.

The general process of calculating a subsidence estimate involves several tasks. Initial basin alluvial section densities and moduli are a function of the applied effective stress on the alluvial sections before groundwater declines began in the model. An increase in effective stress calculated from an increment of groundwater level decline corresponding to a historic period is then applied to the model. From this increase in effective stress loading, the resulting increment of subsidence from each compressible alluvial section is calculated based on its modulus and thickness; the overall subsidence for that period is the sum of the increments of the alluvial sections. With increased effective stress present through the basin alluvial profile, the densities and moduli of the alluvial sections are then recalculated to appropriate higher values to reflect the properties of the compressed alluvial profile. The next increment of groundwater decline and effective stress increase is then applied, and the process is repeated until the complete (simplified) groundwater decline history has been modeled.

Without modification, this PT-based modulus approach would result in immediate subsidence as the groundwater table falls and time-delayed consolidation behavior would not be effectively modeled. Time-delayed consolidation behavior is accounted for in the subsidence predictions by using a simplified exponential decay function.

Stress-strain profiles are modeled utilizing a finite-element geological model that assesses ground subsidence potential and deformation of alluvium in response to changes in groundwater levels in the regional aquifer system. The model is based on the concept that ground strains develop due to differential subsidence resulting from the decline of the water table at depth. Development of this model includes creating a geologic cross-section, applying groundwater decline with time to increase effective stresses within the geologic cross section, and modeling the resulting subsidence. The 2-dimensional subsurface profile is based on available information on geological materials within the subsurface profile and the subsurface geometry supplemented with deep resistivity and other geophysical data. Groundwater decline is based on historic hydrographs from relevant ADWR well records and/or predictive reports available in the literature. Two finite-element-based computer programs, SEEP/W and SIGMA/W, are used to develop the 2-D fully-coupled seepage and stress deformation model. SIGMA/W is used to compute displacements and stresses, and SEEP/W is used to compute changes in pore-water pressure with time. Using these two software products in a coupled manner makes it possible to perform reasonable subsidence and deformation analyses for specified time periods.

The subsidence prediction, PT-based modeling aids in the understanding of alluvial properties and their potential to subside. The stress-strain model estimates the location and magnitude of past, present and future ground strain. For the stress-strain modeling results a value of 0.02% tensional strain is utilized as the threshold for potential earth fissure formation. This value comes from a published value of 0.02 to 0.06% tensional strain for earth fissure development originally published by Jachens and Holzer (1982). The results of these two modeling methods are utilized in combination with all the other investigative methods to delineate earth fissure risk zones. The modeling results are primarily utilized to predict areas likely to experience future differential subsidence and tensional ground strain. The earth fissure risk zones are empirical in their derivation and represent the cumulative sum of all the findings of all methodologies utilized in a given investigation.

5.2.3 PVR Earth Fissure Risk Zones

This section provides an overview of the site-specific hydrogeologic conditions at the PVR sites, the history of earth fissure risk zoning at the PVR sites, and a discussion of monitoring techniques.

Overview of Hydrogeologic Conditions

The project is located within the Sonoran region of the Basin and Range physiographic province and is, in part, separated from the central Phoenix Valley by the bedrock highs of the Tempe Butte area. The following sections discuss aspects of the hydrogeological setting important to an appraisal of ground subsidence and earth fissuring.

Depth to Bedrock

With regard to the PVR area, the buried shape and proximity of the bedrock-alluvium contact are likely the most dominant influences on where earth fissures have formed and where they may form in the future. The Powerline FRS and nearby Hawk Rock are regions where the gradient of the bedrock-alluvium interface is quite pronounced and the thickness of alluvium is variable. These conditions result in a strong potential for differential subsidence, a prerequisite for earth fissure formation. Bedrock is exposed at the ground surface at Hawk Rock, which is located about 4,000 feet west of the bend in the Powerline FRS embankment near Station 110+00. Hawk Rock is the surficial expression of a much larger buried mass of bedrock that partially underlies the Powerline FRS. Understanding this bedrock geometry is one of the most important factors for delineating earth fissure risks for the PVR Rehabilitation or Replacement Project.

Data indicate that the depth to bedrock at the bend in the Powerline FRS embankment at about Station 110+00 is close to or slightly greater than about 300 feet below the ground surface (bgs), that the depth to bedrock from about Powerline Station 50+00 to 105+00 ranges from about 600 to 700 feet bgs, and that north of Station 110+00 the depth to bedrock increases rapidly. These data indicate that depth to bedrock increases very rapidly south of the Powerline FRS. Underneath the northern portion of the Vineyard Road FRS, the depth to bedrock ranges from about 800 feet bgs at Station 345+00 to about 1,700 feet bgs at Station 310+00 to approximately 1,500 feet bgs at Station 280+00. A deep well at about Vineyard Road FRS Station 271+00 encountered conglomerate at a depth of 650 feet bgs and granite at a depth of 1,770 feet bgs. Southward from this point, the data indicate that depth to bedrock continues to increase to depths greater than 2,000 feet bgs.

InSAR provides what is probably the best indication of the shape of the bedrock-alluvium interface in the vicinity of Hawk Rock and the Powerline FRS due to its full map-view and 3D coverage. The most important aspect of this is the indication of the presence of buried bedrock ridges that radiate outward from Hawk Rock and how those implied buried ridges relate to the location of known earth fissures. Most of the known earth fissures near Hawk Rock, and all the known fissures not in the immediate vicinity of Hawk Rock, follow the apparent crest of these implied buried ridges. When comparing InSAR data and U.S. Bureau of Reclamation bedrock elevation data, it appears that InSAR data more accurately indicate the location of the implied buried ridges.

Deep Alluvial Characteristics

A review of selected geophysical data and geologic logs indicates that there are significant lithologic variations present in the alluvial basin profile. The discussion below is summarized from the Initial Subsidence and Earth Fissure Report (AMEC 2010b) and the reader is referred to that report for a detailed discussion of the deep alluvial characteristics.

Geophysical logs in a borehole about 1 mile northwest of Powerline FRS show very low resistivities indicating significant clay content. Based on the amount of subsidence that has occurred in this area, highly compressible clays are anticipated to be present in this area.

The character of the geophysical logs for wells located near, or to the north and west of, the Powerline FRS indicated the presence of zones of significant thickness with resistivities less than about 10 ohm-m. Therefore, subsidence that results from consolidation of clay-rich materials occurs relatively slowly. These areas are shown by InSAR to have been actively subsiding during the 1990s in spite of relatively constant regional groundwater levels.

Historical deep wells were completed near the CAP alignment at or to the south of the Vineyard Road FRS. The character of the geophysical logs for these wells is consistent with the published descriptions of the upper alluvial unit (UAU), and very different from wells completed within the middle fine-grained unit (MFGU) northwest of the Powerline FRS. Between depths of 600 and 1,200 feet bgs, at least 16 zones of higher resistivity (greater than 10 ohm-m), typically at least a few feet thick, could be identified. These higher-resistivity zones were interpreted to contain more granular, higher-permeability materials, rather than clayey material. This alluvial basin section was thus interpreted to include significant interbedded or interfingered units, fluctuating between sandy/gravelly horizons and clay-enriched horizons. With sufficient interconnection of the higher-resistivity, higher-permeability horizons, the basin alluvium could have been drained more rapidly as the groundwater level dropped, and subsidence would have occurred much faster than in the clay-rich alluvium to the north. Geophysical logs indicate that the basin alluvium south of the Vineyard Road FRS appears to be relatively clay poor compared to basin alluvium to the northwest of the Vineyard Road FRS. Below depths of about 1,200 feet bgs the resistivities increased and rarely fell below 10 ohm-m.

Hydrogeologic Conditions

A reasonable estimate of predevelopment groundwater levels can be made from well data indicating a groundwater elevation of about 1,325 feet above mean sea level (amsl), corresponding to a depth to water of approximately 275 feet, in the late 1930s to early 1940s.

In 1978, groundwater levels at the northern and southern ends of the study area had dropped over 200 feet from the estimated predevelopment level, corresponding to a depth to water of about 500 feet bgs or an elevation about 1,100 feet amsl. In the middle of the study area, groundwater levels had dropped less, and were up to about 70 feet higher than in the surrounding area. Suburban growth in the area north of the Powerline FRS, and the establishment of major agriculture to the southwest and west of the Rittenhouse FRS, were probable reasons for the development of major pumping centers in 1978.

By 2009, the water level trend across the PVR study area had changed significantly. Continued suburban development in the northern part of the study area had resulted in continued pumping of groundwater with a further groundwater level decline such that the depth to water was nearly 600 feet bgs. Replacement of pumped groundwater by CAP water delivery for agricultural use resulted in significantly reduced pumping and recovery of groundwater levels by as much as 80 feet from the 1980s to the present. Groundwater levels remained stable or declined moderately (perhaps up to about 40 feet of decline from the 1970s to the present) through the Vineyard Road FRS section of the study area.

Development of Earth Fissure Risk Zones

ADWR has developed groundwater models that predict future groundwater withdrawals given their present, general understandings of the groundwater hydrology of the area and socio-political trends. The Initial Subsidence and Earth Fissure Report (AMEC 2010b) for the PVR Rehabilitation or Replacement Project utilized ADWR predictions for future groundwater withdrawal that were published as part of the East Valley Water Forum Scenarios for the East Salt River Valley Sub-Basin (Hipke 2007). ADWR recently updated it's predictions with Modeling Report No. 22 (Hipke 2010).

As part of the Earth Fissure Risk Zone Investigation Report for the Powerline and Vineyard Road FRSs (AMEC 2006), a stress-strain model was developed for the Powerline FRS embankment. (For a detailed discussion of the model and model parameters, please refer to that report.) One of the modeled scenarios assumed 4 feet per year of groundwater drawdown until the year 2025, whereas other model scenarios were tied to historical groundwater data from predevelopment through 1978, 1986, 1992 and 2004. Based on these predictions, the earth fissure risk zones were originally approximated to reflect the earth fissure risks posed to the Powerline FRS and the northern 1/3 of Vineyard Road FRS through 2025 if current subsidence trends continued. The Initial Subsidence and Earth Fissure Report (AMEC 2010b) updated these risk delineations to account for a design life of 100 years; the level of investigation for the 2010 report was more general and intended for planning purposes and not final design. Any future earth fissure risk zoning studies, either at PVR or any of the District's other flood control structures, should utilize the most current ADWR groundwater predictions, which at the time of publication of this document is Modeling Report No. 22 (Hipke, 2010). The groundwater prediction (or predictions) used in future earth fissure risk zoning studies should be selected by reaching a consensus among stakeholders, since the modeling results are based on a number of variables, both scientific and social-political.

Monitoring

Monitoring strategies currently utilized at Powerline and Vineyard Road FRSs are discussed in detail in the Instrumentation and Monitoring Plan Revision No. 2 (AMEC 2011a). These strategies include 1) review of InSAR products, 2) review of aerial photography and photogeological lineament analyses, 3) monitoring by survey including vertical and horizontal movement, 4) annual ground inspection, and 5) review of regional groundwater conditions.

The purpose of the monitoring system is to obtain the necessary information to identify and assess potential adverse impacts resulting from the potential development of earth fissures and to assess impacts of subsidence on the embankment dam crests. This risk reduction is realized by quantifying the rate and distribution of ground deformation in the vicinity of the structures, coupled with the ability to detect ground rupture along the dam alignments. The system encompasses regions of elevated earth fissure risk along the two structures, with instrumentation located between Powerline FRS Stations 102+50 to 127+50 and Vineyard Road FRS Stations 280+00 to 310+00. Additional instrumentation is proposed for the region between the existing Powerline FRS and the planned Interim Dam Safety Measure (IDSM) and along the alignment of the planned IDSM. The monitoring plan includes the establishment of alert levels and response actions to any exceedance of alert levels.

5.2.4 Recommendations

Many of the outstanding issues associated with earth fissure risk zoning at the PVR FRSs could be addressed through a final design level of subsidence and earth fissure investigation. Such an investigation would likely include additional subsidence refraction profiling, deep resistivity soundings, seismic reflection profiling, future subsidence prediction models and updated stress-strain models. Through such an investigative process the existing earth fissure risk zones would be updated based on a better understanding of site conditions and predicted groundwater declines. This evaluation would include the forthcoming ADWR update to the modeled gravity and depth to bedrock in the area and the updated predictions for groundwater declines as presented in ADWR's Modeling Report No. 22 (Hipke, 2010).

A quantitative risk assessment could also be considered as a means of quantifying the earth fissure risk associated with each earth fissure risk zone, although there would still likely be a large degree of uncertainty at the end of this assessment. This assessment could be supplemented by targeted failure modes and effects analyses that would address specific identified failure modes and lead to the best solution for mitigating the failure mode(s).

For the alternatives evaluation, AMEC recommends the following:

Powerline FRS:

> Structures located within moderate earth fissure risk zones at the Powerline FRS should be planned as hardened structures. Additionally, due to the level of uncertainty, the moderate risk zones in this area are on the higher end of moderate as opposed to the lower end of moderate. It should be anticipated that the planned IDSM will need to be hardened as part of the rehabilitation project.

Vineyard Road FRS:

> Based on our current understanding of earth fissure risk conditions at the Vineyard Road FRS, the section of embankment located within the moderate earth fissure risk zone does not need to be hardened; however, this area should be the subject of a robust monitoring program. Our recommendation is based on our current understanding of the subsurface profile in this area and the results of recent InSAR data. This data suggests the moderate risk zone at the Vineyard Road FRS is on the lower end of moderate as opposed to the higher end of moderate.

It is noted that dam concepts involving earth fissure risk zones mitigated through hardened dam segments and cutoff walls have been taken through the FMEA process (workshop and report) as part of this study and no potential failure modes have been identified for these concepts. It is recommended that any additional concept to be considered for final alternative selection involving earth fissure risk zones without hardened dam segments and/or without cutoffs (such as an embankment dam only with long-term monitoring) should also be taken through an FMEA workshop prior to alternative selection.

6. ENVIRONMENTAL STUDIES

This section provides a summary of the environmental reviews and analyses conducted by Kimley-Horn for the PVR project. The purpose of the environmental investigations was to identify the existing environmental conditions of the PVR structures within the modified easement area and an adjacent buffer area around the easement limits. The environmental evaluation included an overview of the site biology, cultural resources, hazardous materials, social population/demographics, and Section 404 of the Clean Water Act planning considerations. The environmental studies are documented in the following reports.

- "Powerline, Vineyard Road and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project - Biological Evaluation". (Kimley-Horn July, 2010)
- "Powerline, Vineyard Road and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project – Social Population and Demographics Existing Conditions Study". (Kimley-Horn July, 2010)
- "Powerline, Vineyard Road and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project – Cultural Resources Existing Conditions Study". (Kimley-Horn July, 2010)
- "Powerline, Vineyard Road and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project – Hazardous Materials Technical Memorandum". (Kimley-Horn July, 2010)
- "Powerline, Vineyard Road and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project – Significant Nexus Analysis". (Kimley-Horn May, 2012)

6.1 Biological Evaluation

The purpose of the biological evaluation was to document the existing habitat conditions of the project area, and document any species or species specific habitat observed during field biological reconnaissance visits. This assessment focused on gathering general habitat information for the project area and the potential for any threatened, endangered, candidate, or other sensitive species or associated species habitat to occur within the project area.

6.1.1 Habitat Considerations

The majority of the project area is flat and sparsely vegetated, with the majority of the vegetation occurring along the ephemeral washes. Very dense mesquite bosques, containing velvet mesquite (*Prosopis velutina*), blue paloverde (*Parkinsonia florida*), catclaw acacia (*Acacia greggii*), and cottonwoods (*Populus fremontii*) (very rare) are present near and adjacent to the FRSs. The mesquite bosques provide valuable food, shelter, and travel corridors for multiple mammal, avian, and reptile species. Additionally, a higher plant species diversity was observed within the mesquite bosques. The majority of the mesquites observed within the bosque ranged from 20-30 feet in height. The width of the mesquite bosque ranged from 200 feet to over 650 feet.

6.1.2 Threatened and Endangered Species

The Arizona Game and Fish Department's (AGFD) Heritage Data Management System (HDMS) provided a list of special status species that have been documented as occurring within 5 miles of the project area. Additionally, the U.S. Fish and Wildlife Service (USFWS) threatened, endangered, proposed, and candidate species list for Pinal and Maricopa Counties was reviewed by Kimley-Horn's qualified biologist to determine species potentially occurring in the project vicinity. Kimley-Horn's qualified biologist reviewed this list and determined that no threatened, endangered species or their habitat would be potentially affected by a future proposed project.

6.1.3 Species of Concern

The AGFD online review tool did list three "species of concern": the western burrowing owl (*Athene cunicularia hypugaea*), Tucson shovel-nosed snake (*Chionactis occipitalis klauberi*), and pocketed free-tailed bat (*Nyctinomops femorosaccus*) as occurring within 5 miles of the project area. The Tucson shovel-nosed snake was listed by the AGFD as occurring within the project area. The Tucson shovel-nosed snake is listed a candidate species by the USFWS. Candidate species are defined as "Species for which USFWS has sufficient information on biological vulnerability and threats to support proposals to list as Endangered or Threatened under the Endangered Species Act (ESA). However, proposed rules have not yet been issued because such actions are precluded at present by other listing activity". None of these "species of concern" are federally listed species which typically require further analysis for federally funded projects. However, the Tucson shovel-nosed snake is a species that maybe become listed in the near future and the western burrowing owl is protected under the migratory bird act.

6.2 Social Population and Demographics Existing Conditions Study

The "Social Population and Demographics Existing Conditions Study" (Kimley-Horn, 2010) (SPDECS) was completed in preparation for the economic analysis for the PVR project. The purpose of this study is to document the existing social conditions, conduct a preliminary analysis of the data, discuss population and demographic characteristics and identify populations with the potential for disproportionate adverse impacts as part of Phase II of the PVR project.

The boundaries of the study area for SPDECS are the eastern border of the modified easement area upstream of the FRSs on the east, US 60/Superstition Freeway alignment on the north, the East Maricopa Floodway on the west and the Ocotillo Road alignment on the south.

6.2.1 Social Environment

The demographic composition of the study area was calculated using the decennial Census 2000 data sets from the United States Census Bureau (Census 2000). Census tracts (CT) and the block groups (BG) within these census tracts are large, relatively permanent, statistical subdivisions that do not cross county boundaries. For the purposes of the analysis, the demographic composition has been conducted to the block group level.

The PVR FRSs SPDECS area lies within 15 CT containing 21 BG. The CTs and BGs extend beyond the SPDECS area, but not to an extent that the data represents demographic characteristics inconsistent of those strictly within the SPDECS area boundaries. Since the SPDECS area encompasses portions of multiple communities as well as unincorporated county land, data was collected for the Cities of Mesa, Gilbert and Apache Junction, the Town of Queen Creek, both Maricopa and Pinal Counties as well as the State of Arizona. This information was used for comparison purposes in the future analysis of impacts.

The majority of the total population encompassing the PVR FRSs SPDECS area is White (Non-Hispanic) which comprises 86.9% of the population for all the CT/BGs. The total minority population for all the CT/BGs is 13.1% with the breakdown of racial and ethnic demographics as follows: Black or African American 1.4%; American Indian and Alaskan Native 1.0%; Asian 1.2%; Native Hawaiian and other Pacific Islander 0.2%; Other 6.6%; Population of Two or More

Races/Not Hispanic or Latino 2.8%. The percentages of racial, ethnic and total minority populations appear to be consistent with those of the surrounding communities. (*Hispanic or Latino refers to ethnicity and is derived from the total population; 'Hispanic or Latino' is not classified as a separate race. The total minority population minus the Hispanic or Latino is 13.1%.)

The median household income for the PVR FRSs SPDECS area is between $32,055 (CT 3.06, BG 1) and $101,124 (CT 4226.12, BG 2). This represents a slightly lower median income than the neighboring communities. However, the total number of households that are below the poverty level for the study area is less than that of the City of Gilbert, the community with the lowest number (and percentage) of households below the poverty level of those in the project vicinity.

The Title VI Related Statutes minority populations vary by CT and BG but the total percentages for all the CT/BGs combined are as follows: Elderly 18.0%, Disabled 14.5% and Female Head of Household 5.9%. Both the total elderly and disabled populations within the SPDECS area have considerably higher percentages than both Maricopa County and the City of Gilbert.

The Limited English Proficiency (LEP) populations vary by CT and BG, but the total percentages for all the CT/BGs combined are 2.2% and are consistent with those of the surrounding communities.

The existing population demographics were documented to identify the level or degree of total population densities and population densities for the minority groups encompassing the PVR FRSs SPDECS area. In compliance with Title VI and the related statutes, Executive Order 12898, and Executive Order 13166 the populations include racial/ethnic minorities, low-income, elderly, disabled, female head-of-household, and limited English proficiency populations. This data will be used to evaluate and compare impacts to these populations from the alternatives that are developed and analyzed for the project. The alternatives will not have significant impacts on these populations.

6.2.2 Community Cohesion

Community cohesion refers to the aggregate relationship between the quality and quantity of residential interactions. This can be signified by the degree to which residents have a sense of belonging to their neighborhood or community, their level of community participation, and the level to which members of the community interact socially with one another. Community cohesion can be affected by land use planning decisions. Factors associated with community cohesion include the walk-ability of a neighborhood, the level of security or safety within the neighborhood, the quality of public service, the availability of parks and social settings, the population demographics, and the level of neighborly interactions.

Impacts to the communities within the PVR FRSs SPDECS area are anticipated to be minimal and may vary depending on the alternatives developed as part of the PVR FRSs Rehabilitation or Replacement Project in Phase II.

6.2.3 Displacement/Relocation

The displacement of people and businesses is governed by the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, as amended. The purpose of this Act is to ensure the fair and equitable treatment of individuals whose real property is acquired or who are displaced as a result of a federal or federally assisted project. Property ownership, economic impacts and land use (e.g. commercial, residential, or agricultural) will all need to be factored into potential displacement/relocation analysis. No displacement and relocation impacts will result from proposed alternatives formulated for the PVR project.

6.3 Cultural Resources

6.3.1 Existing Conditions Study

Kimley-Horn prepared the “Powerline, Vineyard road and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project Cultural Resources Existing Conditions Study” (Kimley-Horn, July 2010). The purpose of the report was to document the review of the previous cultural resource documentation as part of the existing conditions study for the PVR Rehabilitation or Replacement Project and to determine if additional Class I level studies were needed. The purpose of a Class I Literature Review is to document the previous cultural resource investigations and previously recorded sites/resources within a one mile buffer of a project area.

A review of NRCS project documentation for the flood retarding structures indicates that there were no known cultural resource considerations during original design and construction of the dams. There are also no known cultural considerations during the repairs of the dams conducted by the NRCS during 1978 to 1991.

A Class III cultural resource survey was completed in December 2009 for geotechnical studies related to the PVR FRSs Rehabilitation or Replacement Project. The survey entitled, Class III Cultural Resources Survey Along the Powerline, Vineyard, Rittenhouse Flood Retarding Structures Between Queen Creek and Apache Junction, Pinal County, Arizona (Jones and Florie 2009) included the results of a “site file check” as well as those of the field survey for the specific geotechnical work that was to be performed. The review area for the PVR FRSs 2009 cultural resource study is a one mile buffer around the PVR FRSs structures.

The 2009 Class III report was prepared in compliance with the National Historic Preservation Act of 1966 (as amended); Arizona State Antiquity laws (A.R.S. § 41-841 et seq); and the State Historic Preservation Act (A.R.S. § 41-861 through § 41-864). The site file check for the review area (including the one mile buffer) that was conducted as a component of that report included site records and project files at the State Historic Preservation Office (SHPO) and the AZSITE cultural resource database. Hereinafter, the site file check component of the 2009 Class III survey effort is referred to as the “2009 cultural resource study”.

Previous Research

The 2009 cultural resource study indicated that at least 59 cultural resource investigations/surveys have taken place within the review area. Most of these previous survey areas are linear in nature and cut across the review area. Nine of these surveys are over 10 years old and therefore would require re-evaluation and resurvey in accordance with SHPO guidance. Two other investigations were extensive block surveys, conducted for the Lost Dutchman Heights project areas. These surveys covered portions of the review area in the vicinity of the Powerline FRS.

Previously Recorded Cultural Resources

Within the review area there were 72 previously recorded archaeological sites and one archaeological district identified in the 2009 cultural resource study. Though the vast majority of these sites are prehistoric artifact scatters, some with features of habitation sites (approximately 69), there are several historic sites and an archaeological district.

Of the 72 previously recorded sites, seven have been determined eligible for the National Register of Historic Places (NRHP); 33 are Recommended as eligible for the NRHP; two have been Determined as not eligible; six are Recommended as not eligible; and 24 have not been evaluated. The archaeological district is Recommended as eligible. (Note: Sites "Determined" eligible/not eligible have been evaluated by the SHPO; sites "Recommended" have been evaluated only by their recorder and not the SHPO).

Conclusions and Recommendations

Formal consultation with the Arizona State Historic Preservation Office (SHPO) has been recently initiated following identification of the Preferred Alternative. The initial SHPO consultation correspondence is on file with the NRCS. Consultations with SHPO will continue through the design phase as final alignments, borrow materials, and other disturbance areas are further identified.

Formal consultation with Tribal Historic Preservation Offices (THPOs) have recently been initiated following identification of the Preferred Alternative. The THPO consultation letters are in progress. Consultations with THPOs will continue through the design phase as final alignments, borrow materials, and other disturbance areas are identified.

6.3.2 Cultural Resources Survey

The Sponsor is presently conducting a Class III cultural resources survey for the Area of Potential Effect (APE) for the Preferred Alternative. The purpose of the survey is to conduct a site reconnaissance of the APE for identification and location of cultural resource sites. The APE was prepared to encompass the construction footprint of the preferred alternative for the PVR project. The completion of the site survey is anticipated in late spring 2013. The cultural resources survey will also identify potential sites that may require mitigation due to construction activities. Mitigation will be conducted in a phased approach prior to construction of the elements of the PVR preferred alternative.

6.4 Hazardous Materials Technical Memorandum

Kimley-Horn retained the services of Environmental Data Resources, Inc. (EDR), a third party database search company, to conduct a search of regulated facilities within and in the immediate vicinity of the project area. Based on the results of the EDR search, there were no hazardous material concerns within the project area that should impact the project alternatives.

6.5 Significant Nexus Analysis

Kimley-Horn prepared a Significant Nexus Analysis (SNA) for the Powerline, Vineyard Road and Rittenhouse (PVR) Flood Retarding Structures (FRSs) Rehabilitation or Replacement Project.

6.5.1 Lower Gila River

In October 2008, a 6.9-mile reach of the Lower Gila River from Powers Butte to Gillespie Dam was designated a "traditional navigable water" or TNW by the U.S. Army Corps of Engineers (Corps). Therefore, the nearest TNW to the project area is the Lower Gila River from Powers Butte to Gillespie Dam. The project limits consist of the District's modified easement area

(6,237 acres) with the Arizona State Land Department (ASLD), which includes the FRSs, flood pool areas, Powerline Floodway, and maintenance access roads. This SNA includes the project limits and extends to the TNW via the Powerline Floodway, the East Maricopa Floodway (EMF) and Gila River.

6.5.2 Lost Dutchman Heights

On June 29, 2010, the Corps determined that the 7,700-acre Lost Dutchman Heights (LDH) project (Corps file No. SPL-2008-00674-SDM) and the ephemeral washes within the project area did not have a significant nexus to the TNW (Gila River) and issued an Approved Jurisdictional Delineation that stated there are not waters of the U.S. within the project area. That project and the current PVR project overlap and much of the information in the LDH submittal is also applicable to the PVR project.

6.5.3 Purpose of Significant Nexus Analysis

The purpose of the significant nexus analysis was to assess the flow characteristics and functions of the tributaries within the project area to determine if they significantly affect the chemical, physical, and biological integrity of the TNW. For each of the following situations, a significant nexus exists if the tributary has more than a speculative or insubstantial effect on the chemical, physical and/or biological integrity of the TNW.

Considerations when evaluating significant nexus include, but are not limited to the volume, duration, and frequency of the flow of water in the tributary and its proximity to the TNW, and the functions performed by the tributary. It is not appropriate to determine significant nexus based solely on any specific threshold of distance (e.g. between a tributary and the TNW).

6.5.4 Conclusion of Significant Nexus Analysis

The low frequency of flow events in combination with the peak discharges volumes from the project area ranging from approximately 80 to 150 cfs, the likelihood of flow from the project area reaching the TNW is low. Therefore, the project waters have a low capacity to carry pollutants or flood waters to the TNW, or to reduce the amount of pollutants or flood waters reaching a TNW. Furthermore, the project waters have a low capacity to transfer nutrients and organic carbon that support downstream food webs. The combined peak discharge from the project area (244 cfs) is insignificant in comparison to peak discharge in the TNW (75,883 cfs), and represents 0.3% of the peak flow in the TNW. Therefore, no significant nexus exists with regard to physical and chemical integrity.

The project area provides no habitat for aquatic organisms in the downstream TNW, though ponding areas may provide habitat for several invertebrate species. The only listed species overlap is for the Sonoran desert tortoise which could use ephemeral washes and the adjacent uplands as dispersal habitat. The potential for the project area to contribute biologically to the TNW downstream is unlikely and inconsequential. Furthermore, the project waters have a low capacity to transfer nutrients and organic carbon that support downstream food webs. Therefore, no significant nexus exists with regard to biological integrity.

The waters analyzed do not significantly affect the chemical, physical, and biological integrity of the downstream TNW and therefor appear not to be jurisdictional waters of the U.S. The SNA was submitted to the Corps for concurrence in June 2012. The Corps has submitted the SNA package to the U.S Environmental Protection Agency in January 2013. As of the date of this report concurrence has not been received.

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Appendix E Other Supporting Information

Kimley-Horn and Associates, Inc.

Powerline, Vineyard Road and Rittenhouse Flood Retarding Structures Rehabilitation or Replacement Project

Summary of Operation, Maintenance and Monitoring Quantities for Level III Alternatives Analysis

Designed By: TDD Date: 01/11/2013
Checked By: RAE Date: 01/11/2013

			Alternative 8A		Alternative 8B	
			Rehabilitation/Replacement		Rehabilitation/Replacement	
			Replace Powerline FRS, Convert Rittenhouse FRS to Levee, Rehabilitate Vineyard Road FRS		Replace Powerline FRS, Rehabilitate Vineyard Road and Rittenhouse FRS	
	Unit cost	Unit	Quantity	Cost	Quantity	Cost
Recurring Cost of Powerline, Vineyard Road and Rittenhouse Elements						
Recurring O&M and Monitoring for Engineering Elements						
Estimated Annual Operation and Maintenance						
Vineyard Road FRS						
Dam Embankment	$ 2.00	LF	32,400	$ 64,800	32,200	$ 64,400
Dam Pool to Auxiliary Spillway Crest	$ 100	AC	1,259	$ 125,900	1,195	$ 119,500
SubTotal				$ 190,700		$ 183,900
Rittenhouse FRS						
Dam Embankment	$ 2.00	LF		$ -	21,100	$ 42,200
Levee Embankment	$ 2.00	LF	20,800	$ 41,600		$ -
Dam Pool to Auxiliary Spillway Crest	$ 100	AC		$ -	688	$ 68,800
SubTotal				$ 41,600		$ 111,000
Estimated Annual Monitoring						
Vineyard Road FRS						
Dam in MFRZ - includes FRZ monitoring	$ 14	LF	4,000	$ 56,000	4,000	$ 56,000
Dam or levee in LFRZ	$ 1.20	LF	28,400	$ 34,080	28,200	$ 33,840
SubTotal				$ 90,080		$ 89,840
Rittenhouse FRS						
Dam in MFRZ - includes FRZ monitoring	$ 14	LF		$ -		$ -
Dam or levee in LFRZ	$ 1.20	LF		$ -	21,100	$ 25,320
SubTotal				$ -		$ 25,320
Subtotal Vineyard Road O&M and Monitoring for Engineering Elements				**$ 280,800**		**$ 273,800**
Subtotal Rittenhouse O&M and Monitoring for Engineering Elements				**$ 41,600**		**$ 136,400**
Total Project Cost				**$ 322,400**		**$ 410,200**
100-year Project O&M Cost (I = 3.75%, n=100 years)				**$ 8,380,786**		**$ 10,663,146**

Opinion of Probable Cost for Level III Alternatives Analysis

Designed By: TDD Date: 01/11/2013
Checked By: RAE Date: 01/11/2013

				Alternative 8A		Alternative 8A		Alternative 8B		Alternative 8B		Alternative 8B	
				Rehabilitation/Replacement		Rehabilitation/Replacement		Rehabilitation/Replacement		Rehabilitation/Replacement		Rehabilitation/Replacement	
Line Item	Item Description (Reference the Unit Price Descriptions for additional detail)			Replace Powerline FRS, Convert Rittenhouse FRS to Levee, Rehabilitate Vineyard Road FRS (Upstream Sloping Filter)		Replace Powerline FRS, Convert Rittenhouse FRS to Levee, Rehabilitate Vineyard Road FRS (Hybrid Filter)		Replace Powerline FRS, Rehabilitate Vineyard Road (Upstream Sloping Filter) and Rittenhouse FRS (Upstream Sloping Filter)		Replace Powerline FRS, Rehabilitate Vineyard Road (Hybrid Filter) and Rittenhouse FRS (Hybrid Filter)		Replace Powerline FRS, Rehabilitate Vineyard Road (Hybrid Filter) and Rittenhouse FRS (Central Filter)	
		Unit cost	Unit	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
	FRS Rehabilitation												
	Embankment Rehabilitation												
	Vineyard Road FRS (~32,400 linear ft)												
A1	Excavation	$ 3.00	CY	1,996,000	$ 5,988,000	646,870	$ 1,940,610	1,773,000	$ 5,319,000	644,890	$ 1,934,670	644,890	$ 1,934,670
A2	Structural fill	$ 6.00	CY	2,942,000	$ 17,652,000	1,474,380	$ 8,846,280	2,303,000	$ 13,818,000	1,088,210	$ 6,529,260	1,088,210	$ 6,529,260
A3	Geotextile	$ 2.50	SY	200,000	$ 500,000	164,640	$ 411,600	188,000	$ 470,000	143,000	$ 357,500	143,000	$ 357,500
A4	Filter Material	$ 26.00	CY	258,000	$ 6,708,000	137,200	$ 3,567,200	236,000	$ 6,136,000	119,170	$ 3,098,420	119,170	$ 3,098,420
A5	Gravel Mulch for Engineering	$ 5.50	SY	428,000	$ 2,354,000	413,790	$ 2,275,845	376,000	$ 2,068,000	362,370	$ 1,993,035	362,370	$ 1,993,035
A6	Cutoff wall	$ 10.00	SF	0	$ -	457,040	$ 4,570,400	0	$ -	453,300	$ 4,533,000	453,300	$ 4,533,000
A7	4" Untreated Base	$ 3.00	CY	6,400	$ 19,200	6,400	$ 19,200	6,400	$ 19,200	6,400	$ 19,200	6,400	$ 19,200
A8	Install Earth Fissure Monitoring System	$ 10.00	LF	32,400	$ 324,000	32,400	$ 324,000	32,400	$ 324,000	32,400	$ 324,000	32,400	$ 324,000
	SubTotal				$ 33,545,200		$ 21,955,135		$ 28,154,200		$ 18,789,085		$ 18,789,085
	Rittenhouse FRS (~21,100 linear ft)												
A9	Excavation	$ 3.00	CY					948,000	$ 2,844,000	460,860	$ 1,382,580	227,910	$ 683,730
A10	Structural fill	$ 6.00	CY					1,169,000	$ 7,014,000	722,350	$ 4,334,100	521,100	$ 3,126,600
A11	Geotextile	$ 2.50	SY					118,000	$ 295,000	91,250	$ 228,125	84,880	$ 212,200
A12	Filter Material	$ 26.00	CY					144,000	$ 3,744,000	76,040	$ 1,977,040	70,750	$ 1,839,500
A13	Gravel Mulch for Engineering	$ 5.50	SY					245,000	$ 1,347,500	254,990	$ 1,402,445	254,990	$ 1,402,445
A14	Cutoff wall	$ 10.00	SF					0	$ -	258,000	$ 2,580,000	0	$ -
A15	4" Untreated Base	$ 3.00	CY					4,168	$ 12,504	4,168	$ 12,504	4,168	$ 12,504
A16	Install Earth Fissure Monitoring System	$ 10.00	LF					21,100	$ 211,000	21,100	$ 211,000	21,100	$ 211,000
	SubTotal								$ 15,468,004		$ 12,127,794		$ 7,487,979
	Total FRS Rehabilitation				$ 33,545,200		$ 21,955,135		$ 43,622,204		$ 30,916,879		$ 26,277,064
	Convert Rittenhouse FRS to a Levee												
	Levee Conversion												
	Rittenhouse FRS (~18,700 linear ft)												
B1	Excavation/Removal	$ 3.00	CY	205,030	$ 615,090	205,030	$ 615,090						
B2	Structural Fill	$ 6.00	CY	4,120	$ 24,720	4,120	$ 24,720						
B3	Riprap	$ 65.00	CY	59,390	$ 3,860,350	59,390	$ 3,860,350						
B4	Geotextile	$ 2.50	SY	56,200	$ 140,500	56,200	$ 140,500						
B5	Common Fill	$ 3.00	CY	39,120	$ 117,360	39,120	$ 117,360						
B6	Gravel Mulch for Engineering	$ 5.50	SY	92,340	$ 507,870	92,340	$ 507,870						
	SubTotal				$ 5,265,890		$ 5,265,890						
	Total Convert Rittenhouse FRS to a Levee				$ 5,265,890		$ 5,265,890		$ -		$ -		$ -
	Principal Spillway Modifications												
	Remove Existing Principal Spillway												
D3	Remove Existing Conduit, Cradle, Seepage Collars - Vineyard Road (54-in)	$ 200.00	CY	112	$ 22,400	112	$ 22,400	112	$ 22,400	112	$ 22,400	112	$ 22,400
D4	Coffer Dam around Rittenhouse Principal Outlet (construction and removal)	$ 5.00	CY		$ -		$ -	6,800	$ 34,000	6,800	$ 34,000	6,800	$ 34,000
D5	Remove Existing Conduit, Cradle, Seepage Collars - Rittenhouse (33-in)	$ 150.00	SY	150	$ 22,500	150	$ 22,500	150	$ 22,500	150	$ 22,500	150	$ 22,500
D7	Remove inlet riser/outlet structure - Vineyard Road	$ 2,000.00	EA	2	$ 4,000	2	$ 4,000	2	$ 4,000	2	$ 4,000	2	$ 4,000
D8	Remove inlet riser/outlet structure - Rittenhouse	$ 2,000.00	EA	2	$ 4,000	2	$ 4,000	2	$ 4,000	2	$ 4,000	2	$ 4,000
	SubTotal				$ 52,900		$ 52,900		$ 86,900		$ 86,900		$ 86,900

Opinion of Probable Cost for Level III Alternatives Analysis

Designed By: TDD Date: 01/11/2013
Checked By: RAE Date: 01/11/2013

				Alternative 8A		Alternative 8A		Alternative 8B		Alternative 8B		Alternative 8B	
				Rehabilitation/Replacement		**Rehabilitation/Replacement**		**Rehabilitation/Replacement**		**Rehabilitation/Replacement**		**Rehabilitation/Replacement**	
Line Item	**Item Description (Reference the Unit Price Descriptions for additional detail)**			**Replace Powerline FRS, Convert Rittenhouse FRS to Levee, Rehabilitate Vineyard Road FRS (Upstream Sloping Filter)**		**Replace Powerline FRS, Convert Rittenhouse FRS to Levee, Rehabilitate Vineyard Road FRS (Hybrid Filter)**		**Replace Powerline FRS, Rehabilitate Vineyard Road (Upstream Sloping Filter) and Rittenhouse FRS (Upstream Sloping Filter)**		**Replace Powerline FRS, Rehabilitate Vineyard Road (Hybrid Filter) and Rittenhouse FRS (Hybrid Filter)**		**Replace Powerline FRS, Rehabilitate Vineyard Road (Hybrid Filter) and Rittenhouse FRS (Central Filter)**	
		Unit cost	Unit	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
	New Principal Spillway												
D9	Install 66-in RGRCP and cradle - Vineyard Road	$ 500.00	LF	200	$ 100,000	200	$ 100,000	200	$ 100,000	200	$ 100,000	200	$ 100,000
D10	Install 42-in RGRCP and cradle - Rittenhouse	$ 300.00	LF		$ -		$ -	200	$ 60,000	200	$ 60,000	200	$ 60,000
D11	USBR Type VI Outlet Structure - Vineyard Road	$ 15,000.00	EA	1	$ 15,000	1	$ 15,000	1	$ 15,000	1	$ 15,000	1	$ 15,000
D12	USBR Type VI Outlet Structure - Rittenhouse	$ 15,000.00	EA		$ -		$ -	1	$ 15,000	1	$ 15,000	1	$ 15,000
D13	NRCS T-Top Single Stage Riser Inlet - Vineyard Road	$ 25,000.00	EA	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000
D14	NRCS T-Top Single Stage Riser Inlet - Rittenhouse	$ 25,000.00	EA		$ -		$ -	1	$ 25,000	1	$ 25,000	1	$ 25,000
	SubTotal				$ 140,000		$ 140,000		$ 240,000		$ 240,000		$ 240,000
	Total Principal Spillway Modifications				$ 192,900		$ 192,900		$ 326,900		$ 326,900		$ 326,900
	Auxiliary Spillway Improvements - Vineyard Road												
	New Dam Segment Extensions (North and South)												
E1	Excavation	$ 3.00	CY	187,754	$ 563,300	187,754	$ 563,300	187,754	$ 563,300	187,754	$ 563,300	187,754	$ 563,300
E2	Structural Fill	$ 6.00	CY	88,473	$ 530,900	88,473	$ 530,900	88,473	$ 530,900	88,473	$ 530,900	88,473	$ 530,900
E3	Geotextile	$ 2.50	SY	11,950	$ 29,900	11,950	$ 29,900	11,950	$ 29,900	11,950	$ 29,900	11,950	$ 29,900
E4	Filter Material	$ 26.00	CY	15,818	$ 411,300	15,818	$ 411,300	15,818	$ 411,300	15,818	$ 411,300	15,818	$ 411,300
E5	Untreated Base	$ 3.00	CY	2,422	$ 7,300	2,422	$ 7,300	2,422	$ 7,300	2,422	$ 7,300	2,422	$ 7,300
E6	Common Fill	$ 3.00	CY	90,466	$ 271,400	90,466	$ 271,400	90,466	$ 271,400	90,466	$ 271,400	90,466	$ 271,400
	Subtotal				$ 1,814,100		$ 1,814,100		$ 1,814,100		$ 1,814,100		$ 1,814,100
	Modify North Auxiliary (Emergency) Spillway												
E7	Excavation for Drop Structure	$ 3.00	CY	11,690	$ 35,100	11,690	$ 35,100	11,690	$ 35,100	11,690	$ 35,100	11,690	$ 35,100
E8	Drop Structure Quantity (concrete and reinforcement)	$ 450.00	CY	905	$ 407,400	905	$ 407,400	905	$ 407,400	905	$ 407,400	905	$ 407,400
E9	Aggregate Base	$ 22.00	CY	907	$ 20,000	907	$ 20,000	907	$ 20,000	907	$ 20,000	907	$ 20,000
E10	General Riprap	$ 50.00	CY	19,973	$ 998,700	19,973	$ 998,700	19,973	$ 998,700	19,973	$ 998,700	19,973	$ 998,700
E11	Apron Riprap	$ 65.00	CY	2,043	$ 132,800	2,043	$ 132,800	2,043	$ 132,800	2,043	$ 132,800	2,043	$ 132,800
E12	Decomposed Granite	$ 5.50	SY	23,668	$ 130,200	23,668	$ 130,200	23,668	$ 130,200	23,668	$ 130,200	23,668	$ 130,200
E13	Filter Material/Toe Drain	$ 30.00	CY	809	$ 24,300	809	$ 24,300	809	$ 24,300	809	$ 24,300	809	$ 24,300
E14	Drain Rock	$ 50.00	CY	260	$ 13,100	260	$ 13,100	260	$ 13,100	260	$ 13,100	260	$ 13,100
E15	Geotextile	$ 2.50	SY	33,204	$ 83,100	33,204	$ 83,100	33,204	$ 83,100	33,204	$ 83,100	33,204	$ 83,100
E16	Structural Fill for Dikes	$ 6.00	CY	21,892	$ 131,400	21,892	$ 131,400	21,892	$ 131,400	21,892	$ 131,400	21,892	$ 131,400
	Subtotal				$ 1,976,100		$ 1,976,100		$ 1,976,100		$ 1,976,100		$ 1,976,100
	Modify South Auxiliary (Emergency) Spillway												
E17	Excavation for Drop Structure	$ 3.00	CY	12,192	$ 36,600	12,192	$ 36,600	12,192	$ 36,600	12,192	$ 36,600	12,192	$ 36,600
E18	Drop Structure Quantity (concrete and reinforcement)	$ 450.00	CY	897	$ 403,900	897	$ 403,900	897	$ 403,900	897	$ 403,900	897	$ 403,900
E19	Aggregate Base	$ 22.00	CY	705	$ 15,600	705	$ 15,600	705	$ 15,600	705	$ 15,600	705	$ 15,600
E20	General Riprap	$ 50.00	CY	15,827	$ 791,400	15,827	$ 791,400	15,827	$ 791,400	15,827	$ 791,400	15,827	$ 791,400
E21	Apron Riprap	$ 65.00	CY	2,043	$ 132,800	2,043	$ 132,800	2,043	$ 132,800	2,043	$ 132,800	2,043	$ 132,800
E22	Decomposed Granite	$ 5.50	SY	17,952	$ 98,800	17,952	$ 98,800	17,952	$ 98,800	17,952	$ 98,800	17,952	$ 98,800
E23	Filter Material/Toe Drain	$ 30.00	CY	809	$ 24,300	809	$ 24,300	809	$ 24,300	809	$ 24,300	809	$ 24,300
E24	Drain Rock	$ 50.00	CY	260	$ 13,100	260	$ 13,100	260	$ 13,100	260	$ 13,100	260	$ 13,100
E25	Geotextile	$ 2.50	SY	26,557	$ 66,400	26,557	$ 66,400	26,557	$ 66,400	26,557	$ 66,400	26,557	$ 66,400
E26	Structural Fill for Dikes	$ 6.00	CY	16,606	$ 99,700	16,606	$ 99,700	16,606	$ 99,700	16,606	$ 99,700	16,606	$ 99,700
	Subtotal				$ 1,682,600		$ 1,682,600		$ 1,682,600		$ 1,682,600		$ 1,682,600
	Total Auxiliary Spillway Improvements - Vineyard Road				$ 5,472,800		$ 5,472,800		$ 5,472,800		$ 5,472,800		$ 5,472,800

Opinion of Probable Cost for Level III Alternatives Analysis

Designed By: TDD Date: 01/11/2013
Checked By: RAE Date: 01/11/2013

				Alternative 8A		Alternative 8A		Alternative 8B		Alternative 8B		Alternative 8B	
				Rehabilitation/Replacement		Rehabilitation/Replacement		Rehabilitation/Replacement		Rehabilitation/Replacement		Rehabilitation/Replacement	
Line Item	Item Description (Reference the Unit Price Descriptions for additional detail)			Replace Powerline FRS, Convert Rittenhouse FRS to Levee, Rehabilitate Vineyard Road FRS (Upstream Sloping Filter)		Replace Powerline FRS, Convert Rittenhouse FRS to Levee, Rehabilitate Vineyard Road FRS (Hybrid Filter)		Replace Powerline FRS, Rehabilitate Vineyard Road (Upstream Sloping Filter) and Rittenhouse FRS (Upstream Sloping Filter)		Replace Powerline FRS, Rehabilitate Vineyard Road (Hybrid Filter) and Rittenhouse FRS (Hybrid Filter)		Replace Powerline FRS, Rehabilitate Vineyard Road (Hybrid Filter) and Rittenhouse FRS (Central Filter)	
		Unit cost	Unit	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
	Auxiliary Spillway Improvements - Rittenhouse												
	New Dam Segment Extension												
E27	Excavation	$ 3.00	CY					164,339	$ 493,100	164,339	$ 493,100	164,339	$ 493,100
E28	Structural Fill	$ 6.00	CY					85,267	$ 511,700	85,267	$ 511,700	85,267	$ 511,700
E29	Geotextile	$ 2.50	SY					7,555	$ 18,900	7,555	$ 18,900	7,555	$ 18,900
E30	Filter Material	$ 26.00	CY					8,035	$ 209,000	8,035	$ 209,000	8,035	$ 209,000
E31	Untreated Base	$ 3.00	CY					2,245	$ 6,800	2,245	$ 6,800	2,245	$ 6,800
E32	Common Fill	$ 3.00	CY					77,758	$ 233,300	77,758	$ 233,300	77,758	$ 233,300
	Subtotal								$ 1,472,800		$ 1,472,800		$ 1,472,800
	CLSM Sill												
E33	Control Sill excavation volume - Rittenhouse	$ 5.00	CY					1,511	$ 7,600	1,511	$ 7,600	1,511	$ 7,600
E34	Construct CLSM sill at control section - Rittenhouse	$ 150.00	CY					1,511	$ 226,700	1,511	$ 226,700	1,511	$ 226,700
E35	Rittenhouse riprap basin downstream of control section, D_{50}=12"	$ 65.00	CY					1,500	$ 97,500	1,500	$ 97,500	1,500	$ 97,500
E36	Earthwork to raise Rittenhouse spillway crest and level section	$ 3.00						66,900	$ 200,700	66,900	$ 200,700	66,900	$ 200,700
	SubTotal								$ 532,500		$ 532,500		$ 532,500
	Total Auxiliary Spillway Improvements - Rittenhouse				$ -		$ -		$ 2,005,300		$ 2,005,300		$ 2,005,300
	Existing Irrigation Outlet Removals												
	Remove Existing Irrigation Outlets												
F1	Coffer Dam around outlet - Rittenhouse (Sta 68+50)	$ 3.00	CY		$ -		$ -	8,800	$ 26,400	8,800	$ 26,400	8,800	$ 26,400
F2	Coffer Dam around outlet - Rittenhouse (Sta 156+00)	$ 3.00	CY		$ -		$ -	8,400	$ 25,200	8,400	$ 25,200	8,400	$ 25,200
F4	Remove Existing 24-in RCP and headwalls - Rittenhouse (Sta 68+50)	$ 300.00	LF	126	$ 37,800	126	$ 37,800	126	$ 37,800	126	$ 37,800	126	$ 37,800
F5	Remove Existing 24-in RCP and headwalls - Rittenhouse (Sta 156+00)	$ 300.00	LF	139	$ 41,700	139	$ 41,700	139	$ 41,700	139	$ 41,700	139	$ 41,700
	SubTotal				$ 79,500		$ 79,500		$ 131,100		$ 131,100		$ 131,100
	Total Existing Irrigation Outlet Removals				$ 79,500		$ 79,500		$ 131,100		$ 131,100		$ 131,100
	Site Preparation												
	Clearing and Grubbing												
L1	Clearing and Grubbing	$ 12,000.00	AC	274	$ 3,288,000	274	$ 3,288,000	274	$ 3,288,000	274	$ 3,288,000	274	$ 3,288,000
	SubTotal				$ 3,288,000		$ 3,288,000		$ 3,288,000		$ 3,288,000		$ 3,288,000
	Total Site Preparation				$ 3,288,000		$ 3,288,000		$ 3,288,000		$ 3,288,000		$ 3,288,000

Opinion of Probable Cost for Level III Alternatives Analysis

Designed By: TDD Date: 01/11/2013
Checked By: RAE Date: 01/11/2013

Line Item	Item Description (Reference the Unit Price Descriptions for additional detail)	Unit cost	Unit	Alternative 8A Rehabilitation/Replacement: Replace Powerline FRS, Convert Rittenhouse FRS to Levee, Rehabilitate Vineyard Road FRS (Upstream Sloping Filter)		Alternative 8A Rehabilitation/Replacement: Replace Powerline FRS, Convert Rittenhouse FRS to Levee, Rehabilitate Vineyard Road FRS (Hybrid Filter)		Alternative 8B Rehabilitation/Replacement: Replace Powerline FRS, Rehabilitate Vineyard Road (Upstream Sloping Filter) and Rittenhouse FRS (Upstream Sloping Filter)		Alternative 8B Rehabilitation/Replacement: Replace Powerline FRS, Rehabilitate Vineyard Road (Hybrid Filter) and Rittenhouse FRS (Hybrid Filter)		Alternative 8B Rehabilitation/Replacement: Replace Powerline FRS, Rehabilitate Vineyard Road (Hybrid Filter) and Rittenhouse FRS (Central Filter)	
		Unit cost	Unit	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
	Subtotal Vineyard Road Structures				**$ 39,184,400**		**$ 27,594,400**		**$ 33,793,400**		**$ 24,428,300**		**$ 24,428,300**
	Subtotal Rittenhouse Structures				**$ 5,371,900**		**$ 5,371,900**		**$ 17,765,000**		**$ 14,424,700**		**$ 9,784,900**
	Subtotal Additional Elements				**$ 3,288,000**		**$ 3,288,000**		**$ 3,288,000**		**$ 3,288,000**		**$ 3,288,000**
	Subtotal Structure Cost				**$ 47,844,300**		**$ 36,254,300**		**$ 54,846,400**		**$ 42,141,000**		**$ 37,501,200**
	Landscaping and Aesthetics "Lite" Approach (5%)				$ 2,392,300		$ 1,812,800		$ 2,742,400		$ 2,107,100		$ 1,875,100
	Environmental Mitigation				$ 1,218,000		$ 1,218,000		$ 1,758,000		$ 1,758,000		$ 1,758,000
	Cultural Resources Mitigation				$ 2,408,000		$ 2,408,000		$ 2,408,000		$ 2,408,000		$ 2,408,000
	Contingency (25%)				$ 11,961,100		$ 9,063,600		$ 13,711,600		$ 10,535,300		$ 9,375,300
	Subtotal Structure, Environmental and Landscape Cost				**$ 65,823,700**		**$ 50,756,700**		**$ 75,466,400**		**$ 58,949,400**		**$ 52,917,600**
	ADWR Permit (2% dams)				$ 1,317,000		$ 1,016,000		$ 1,510,000		$ 1,179,000		$ 1,059,000
	Mobilization (3%)				$ 1,975,000		$ 1,523,000		$ 2,264,000		$ 1,769,000		$ 1,588,000
	Engineering (3%)				$ 1,975,000		$ 1,523,000		$ 2,264,000		$ 1,769,000		$ 1,588,000
	Supplemental General Conditions (1%)				$ 659,000		$ 508,000		$ 755,000		$ 590,000		$ 530,000
	CQC Plan and Testing (1%)				$ 659,000		$ 508,000		$ 755,000		$ 590,000		$ 530,000
	Construction Management (3%)				$ 1,975,000		$ 1,523,000		$ 2,264,000		$ 1,769,000		$ 1,588,000
	Total Project Cost				**$ 74,383,700**		**$ 57,357,700**		**$ 85,278,400**		**$ 66,615,400**		**$ 59,800,600**

Appendix F Compact Disk (CD)